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ABSTRACT

This curriculum guide contains teacher and student materials for a course on outboard-engine boat systems and service for power product equipment technician occupations. The course contains the following four units of instruction: (1) Outboard-Engine Design and Identification; (2) Operation and Service of Engine-Support Systems; (3) Operation and Service of Power-Output Systems; and (4) Operation and Service of Control and Safety Systems. Each section in the teacher edition includes some or all of the following components for each of the four units of instruction: suggested activities, answers to assignment sheets, written test with answers, unit evaluation form, transparency masters, and worksheet masters. The teacher edition also includes a competency profile, an instructional and task analysis, academic and workplace skill classifications and definitions, and a list of related academic and workplace skills. All of the unit components focus on measurable and observable learning outcomes. Each instructional unit in the student edition includes some or all of the following components: objective sheet, information sheet, student supplements, assignment sheets, and job sheets. (KC)

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Power Product Equipment Technician:

Outboard-Engine Systems and Service

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Outboard-Engine Systems and Service

Teacher Edition

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Foreword

Power Product Equipment Technician: Outboard-Engine Systems and Service and *Power Product Equipment Technician: Outboard-Engine Boat Systems* are two companion publications in a series of new publications developed to replace MAVCC's previous small-engine series.

Three publications in the new *Power Product Equipment Technician* series have been developed to replace the core publication for MAVCC's previous small-engine series.

- The first publication, *Theory and Principles of Engine Operation,* is divided into two sections: Section A, "Orientation," and Section B, "Basic Engine Theory and Operation." Section A covers basic workplace safety and first aid, common hand tools, common fasteners, and related math and measuring. Section B addresses reference materials; basic engine principles; engine design and identification; engine operation; and parts management, inventory control, and service orders.
- The second publication, *Engine Systems and Service,* is also divided into two sections: Section A, "Engine Systems," and Section B, "Engine Overhaul." Section A covers lubrication systems, cooling systems, fuel systems, governor systems, basic electrical principles, ignition systems, starting systems, charging systems, and exhaust systems. Section B addresses engine overhaul, troubleshooting, and failure analysis.
- *Equipment Systems,* the third publication, consists of seven units that cover principles of power transmission, mechanical drive systems, principles of fluid power, hydraulic and pneumatic drive systems, wheel and brake systems, chassis and steering systems, and chassis electrical systems.

Other publications have been developed as spin-off books from the three new core publications. These spin-off publications include *Lawn and Garden Equipment, Construction Equipment,* and the two companion publications *Outboard-Engine Systems and Service* and *Outboard-Engine Boat Systems.*

- *Lawn and Garden Equipment* contains an introduction to lawn and garden equipment, a unit on light-duty lawn and garden equipment (walk-behind lawn mowers, edgers, trimmers, dethatchers, blowers, hedge clippers, snow blowers, and pressure washers), a unit on heavy-duty lawn and garden equipment (garden tractors, riding lawn mowers, tillers, log splitters, and shredders), and a unit on chain saws.
- *Construction Equipment* contains three units: a unit on concrete equipment (powered concrete mixers, tampers, vibrators, floats, trowels, and screeds), a unit on water pumps and air compressors, and a unit on alternators, generators, and welding equipment.
- *Outboard-Engine Systems and Service* contains four units: a unit on outboard-engine design and identification, a unit on operation and service of engine-support systems, a unit on the operation and service of power-output systems, and a unit on the operation and service of control and safety systems. *Outboard-Engine Boat Systems* contains three units: an orientation to outboard-engine boat systems and rigging, a unit on trailers and safe towing and boat operation, and a unit on seasonal procedures.

These new instructional materials reflect the changes that have occurred in the industry as a result of emerging technology and the demand for more highly skilled workers. The growing need for entry-level workers to be able to read and interpret information provided in manufacturers' service manuals has prompted us to include student supplements and assignment sheets that teach students how to use reference materials and to create job sheets with worksheets that require students to obtain specific information from a related service manual before completing a specific task.

Foreword

Today's workers also need a stronger foundation in theoretical concepts and principles to help them better understand how engine systems and equipment components interrelate, and the information sheets and student supplements in the student edition have been designed to help provide that foundation.

The success of this publication is due in large part to the capabilities of the personnel who worked with its development. Appreciation is extended to them for their valuable contributions to the publication.

These instructional materials are designed for student use and to assist teachers in organizing and improving instruction. These instructional materials are based on the curriculum-alignment concept of first stating the objectives (objective sheet), developing instructional strategies for teaching to those objectives (information, assignment, and job sheets), and assessing to those same objectives (written test—a criterion-referenced evaluation instrument).

Every effort has been made to make these materials basic, readable, and by all means, usable. However, as with all of MAVCC's instructional materials, teachers must localize and personalize these materials to meet their community, classroom/laboratory, and individual student's situation. Teachers are encouraged to supplement the instructional materials and to develop strategies for motivating their students.

Special attention should be given to the matrix identifying basic academic skills being reinforced in these instructional materials as well as the suggestions on ways to increase reinforcement of academic and workplace skills. By reinforcing these skills, the instructor should assist students in improving their employability skills.

As you use these instructional materials, we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improvement of the materials, please call or write us.

Jim Fliehler, Chair
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Vocational Curriculum Consortium, Inc.

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Use of Introductory Materials

Introductory materials are included in the teacher edition only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information—such as the table of contents, foreword, and acknowledgments page—information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/learning process.
2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This profile becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.
3. **Instructional/task analysis**—Provides a quick review of the contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.
4. **Academic and workplace skill classifications and definitions**—Defines the basic-skill classifications used by MAVCC. Skill areas reflected by skill groups, subskills, and descriptions have been identified using *What Work Requires of Schools: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want*. These have been adapted by MAVCC.
5. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and job sheets) according to related academic and workplace skills being reinforced.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

Power Product Equipment Technician: Outboard-Engine Systems and Service contains four units of instruction:

- Unit 1: Outboard-Engine Design and Identification
- Unit 2: Operation and Service of Engine-Support Systems
- Unit 3: Operation and Service of Power-Output Systems
- Unit 4: Operation and Service of Control and Safety Systems

Each instructional unit in a student edition includes some or all of the following components: objective sheet, information sheet, student supplements, assignment sheets, and job sheets.

Each section in this teacher edition includes some or all of the following components for each of the four units of instruction: suggested activities, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, transparency masters, and worksheet masters.

All of the unit components focus on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for teacher demonstrations.
- Amount of time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource people who must be contacted.

Student-edition components

It is a challenge to keep students motivated. Instructors should supplement the student-edition components by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each component can best be taught. Allow students to become involved in preparing and planning their teaching/learning experiences.

Objective sheet. Each unit of instruction is based on performance objectives that state the goals for successful completion of the course. These performance objectives are stated in two forms: unit objectives, which state the expected performance of each student after completion of the unit of instruction, and specific objectives, which state what the student must do to reach the unit objective.

The objectives should be stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information-sheet, assignment-sheet, job-sheet, and written-test items.

Information sheet. The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide information for the teaching of each objective.

Student supplements. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students will need in order to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information is evaluated in the completion of assignment and/or job sheets.

Assignment sheets. Assignment sheets provide students with pencil-and-paper activities that give students the opportunity to make practical application of the knowledge in the information sheet and student supplements. Criteria are provided to objectively evaluate student performance.

Job sheets. Job sheets are an important segment of each unit; they give the instructor direction as to the psychomotor skills to be taught and allow both the student and instructor to check student progress toward the accomplishment of those skills. The worksheet included in each job sheet provides criteria to allow the instructor to objectively evaluate student performance of a particular psychomotor skill. The instructor should discuss the equipment and materials to be used—emphasizing the specific equipment and materials available in the classroom and/or laboratory—and demonstrate the job-sheet procedure before having students practice the psychomotor skill.

Teacher-edition components

Suggested activities. The suggested activities assist teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the teaching suggestions, and skill areas have been noted in bold. The teacher should read the suggested activities before teaching a unit and decide how each objective can best be taught. Time should also be allowed to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or objectives in the area covered.

Assignment-sheet and written-test answers. Assignment-sheet answers and written-test answers are designed to assist the teacher in evaluating student performances on the assignment sheets and written test.

Use of This Publication

Written test. This component is a criterion-referenced evaluation of every cognitive objective listed in the information sheet. If the instructor has added, deleted, or modified objectives, appropriate changes should be made on the written test. It is recommended that the test be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired. The test is included in the teacher edition only, but duplication is permitted for student use.

Unit evaluation form. This form provides teachers with a record of each student's performance on a unit of instruction. It includes space for assignment-sheet ratings, job-sheet ratings, written-test scores, and teacher comments. The unit evaluation form may also be duplicated for student use.

Transparency masters. Transparency masters are used to direct the students' attention to the topic of discussion. Transparency masters may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction.

Teacher supplements. Teacher supplements are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher-level materials to stretch the advanced student, with remedial information or practice to assist the less-advanced student, and with state-of-the-art information in which the teacher may not have background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

Worksheet masters. Worksheet masters provide the instructor with masters for making photocopies of the evaluation criteria used to evaluate student performance of the psychomotor skills (job sheets) included in the student edition.

Competency Profile

Name: ____

Directions: Evaluate the student using the rating scale below. Write the appropriate number/letter to indicate the degree of competency achieved. The descriptions associated with each of the numbers/letters focus on a level of student performance for each of the tasks listed. The written-test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Optional rating scales

Option A

Rating scale:

4 – **Skilled** – Can perform job with no additional training.
3 – **Moderately Skilled** – Has performed job during training program; limited additional training may be required.
2 – **Limited Skill** – Has performed job during training program; additional training is required to develop skill.
1 – **Unskilled** – Is familiar with process, but is unable to perform job.
0 – **No Exposure** – No information or practice provided during training program; complete training required.
NA – **Non-applicable**.

Option B

Yes – Can perform with no additional training.
No – Is unable to perform satisfactorily.

Unit 1: Outboard-Engine Design and Identification

_______ 1. Interpret outboard-engine labels
_______ 2. Classify outboard-engine designs by their valve and cylinder arrangements
_______ 3. Complete outboard-engine information forms
_______ 4. ____

_______Written-test score

Unit 2: Operation and Service of Engine-Support Systems

_______ 1. Select the correct fuel and oil for outboard-engine applications
_______ 2. Determine parts and specifications for engine-support systems
_______ 3. Determine outboard-engine tune-up specifications and parts requirements
_______ 4. Interpret an outboard-engine troubleshooting chart
_______ 5. Fuel, start, operate, and shut down outboard engines
_______ 6. Perform routine maintenance on fuel systems
_______ 7. Repair fuel systems
_______ 8. Perform routine maintenance on lubrication systems
_______ 9. Repair lubrication systems
_______10. Perform routine maintenance on cooling systems
_______11. Repair cooling systems
_______12. Perform routine maintenance on ignition systems
_______13. Repair ignition systems
_______14. Perform routine maintenance on starting systems
_______15. Repair starting systems
_______16. Perform routine maintenance on charging systems
_______17. Repair charging systems

Competency Profile

Unit 2: **Operation and Service of Engine-Support Systems** (cont.)

_______18. Perform minor tune-ups
_______19. Perform major tune-ups
_______20. Troubleshoot failure-to-start in outboard engines
_______21. Perform failure analysis on outboard engines
_______22. ____

_______Written-test score

Unit 3: **Operation and Service of Power-Output Systems**

_______ 1. Determine parts and specifications for power-output systems
_______ 2. Interpret a power-output-system troubleshooting chart
_______ 3. Calculate gear ratios
_______ 4. Determine correct propeller characteristics for specific applications
_______ 5. Perform routine maintenance on power-output systems
_______ 6. Repair power-output systems
_______ 7. Remove and replace propellers
_______ 8. Check rpm on propellers
_______ 9. Perform failure analysis on power-output-system components
_______10. ____

_______Written-test score

Unit 4: **Operation and Service of Control and Safety Systems**

_______ 1. Determine control-system and safety-system service specifications and parts requirements
_______ 2. Perform routine maintenance on steering systems
_______ 3. Repair steering systems
_______ 4. Perform routine maintenance on tilt and trim systems
_______ 5. Repair tilt and trim systems
_______ 6. Perform routine maintenance on remote-control systems
_______ 7. Repair remote-control systems
_______ 8. Service safety systems
_______ 9. ____

_______Written-test score

Comments: ____

____

____

____

____

Evaluator: _______________________ **Date:** _______________

Permission to duplicate this profile is granted.

Instructional/Task Analysis

Related information: What the student should know	Application: What the student should be able to do
Unit 1: Outboard-Engine Design and Identification	
1. Characteristics used to identify outboard engines	11. Interpret outboard-engine labels
2. Major sections of outboard engines and their purposes	12. Classify outboard-engine designs by their valve and cylinder arrangements
3. Major components of outboard engines and their functions	13. Complete outboard-engine information forms
4. Description of the combustion cycle of two-stroke-cycle outboard engines	
5. Description of the combustion cycle of four-stroke-cycle outboard engines	
6. Descriptions of the major systems used in outboard engines	
7. Types of pistons commonly used in outboard engines and their applications	
8. Types of valves commonly used in outboard engines	
9. Cylinder arrangements commonly used in outboard engines	
10. Valve arrangements commonly used in outboard engines	
Unit 2: Operation and Service of Engine-Support Systems	
1. Definition of the term *engine-support system*	
2. Major engine-support systems used in outboard engines	
3. Description of the typical fuel systems used in outboard engines	
4. Types of fuels used in outboard engines and their applications	
5. Factors considered in the design of outboard-engine fuel tanks and their descriptions	

Related information: What the student should know

Application: What the student should be able to do

Unit 2: Operation and Service of Engine-Support Systems (cont.)

6. Probable causes of fuel-system problems
7. Description of the typical lubrication systems used in outboard engines
8. Description of the typical cooling systems used in outboard engines
9. Types of water pumps commonly used in outboard-engine cooling systems and their descriptions
10. Principles of operation of volume-type water pumps
11. Principles of operation of pressure-type water pumps
12. Principles of operation of outboard-engine ignition systems
13. Types of tests performed on outboard-engine ignition systems and their purposes
14. Tools and instruments used to test ignition systems and their purposes
15. Probable causes of ignition-system problems
16. Description of the typical starting systems used in outboard engines
17. Description of the typical charging systems used in outboard engines
18. Purpose of battery isolators
19. Description of the typical exhaust systems used in outboard engines
20. Probable causes of engine overheating
21. Typical tasks performed for engine tune-ups and their definitions
22. Guidelines for performing engine tune-ups

23. Select the correct fuel and oil for outboard-engine applications
24. Determine parts and specifications for engine-support systems
25. Determine outboard-engine tune-up specifications and parts requirements
26. Interpret an outboard-engine trouble-shooting chart
27. Fuel, start, operate, and shut down outboard engines
28. Perform routine maintenance on fuel systems
29. Repair fuel systems
30. Perform routine maintenance on lubrication systems.
31. Repair lubrication systems
32. Perform routine maintenance on cooling systems
33. Repair cooling systems
34. Perform routine maintenance on ignition systems
35. Repair ignition systems
36. Perform routine maintenance on starting systems
37. Repair starting systems
38. Perform routine maintenance on charging systems
39. Repair charging systems
40. Perform minor tune-ups
41. • Perform major tune-ups

Instructional/Task Analysis

Related information: What the student should know	Application: What the student should be able to do
Unit 2: Operation and Service of Engine-Support Systems (cont.)	
	42. Troubleshoot failure-to-start in outboard engines
	43. Perform failure analysis on outboard engines
Unit 3: Operation and Service of Power-Output Systems	
1. Description of the typical power-output systems used in outboard engines	14. Determine parts and specifications for power-output systems
2. Major components of power-output systems and their functions	15. Interpret a power-output-system troubleshooting chart
3. Design features used to classify power-output systems	16. Calculate gear ratios
4. Principles of operation of mechanical-shifting power-output systems	17. Determine correct propeller characteristics for specific applications
5. Major components of outboard-engine propeller assemblies and their functions	18. Perform routine maintenance on power-output systems
6. Materials used in the manufacture of outboard-engine propellers	19. Repair power-output systems
7. Description of the principles of propeller rotation and counter-rotation	20. Remove and replace propellers
8. Design features used to classify propeller hubs	21. Check rpm on propellers
9. Types of propeller defects and their definitions	22. Perform failure analysis on power-output-system components
10. Guidelines for sending a propeller to a repair facility	
11. Safety rules for servicing power-output systems	
12. Probable causes of poor boat performance related to power-output systems	
13. Methods used to compensate for walking	

Instructional/Task Analysis

Related information: What the student should know	Application: What the student should be able to do
Unit 4: Operation and Service of Control and Safety Systems	
1. Definitions of the terms *control system* and *safety system*	15. Determine control-system and safety-system service specifications and parts requirements
2. Types of control systems used with outboard engines and their functions	16. Perform routine maintenance on steering systems
3. Classifications of outboard-engine control systems and their definitions	17. Repair steering systems
4. Types of steering systems used with outboard engines and their definitions	18. Perform routine maintenance on tilt and trim systems
5. Definitions of the terms *tilt, trim,* and *trim tab*	19. Repair tilt and trim systems
6. Description of the effect of trim tab on boat performance	20. Perform routine maintenance on remote-control systems
7. Purposes of the trim tab	21. Repair remote-control systems
8. Types of hydraulic circuits used in outboard-engine control systems and their purposes	22. Service safety systems
9. Types of hydraulic cylinders used in outboard-engine control systems	
10. Types of hydraulic fluids used in tilt and trim systems	
11. Guidelines for filling hydraulic systems	
12. Major components of remote-control assemblies and their functions	
13. Functions of the safety systems used with outboard engines	
14. Principles of operation of emergency-stop lanyards	

Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
	Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
	Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Listening	Receiving, interpreting, and responding to verbal messages and other cues.
	Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
Thinking skills	Creative thinking	Using imagination to generate new ideas.
	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
	Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills.
	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Career awareness, development, and mobility	Assessing self accurately, setting personal goals, establishing and implementing a plan, and monitoring progress.
	Integrity/honesty	Choosing an ethical course of action when faced with making a decision that may break with personal or societal values and recognizing the impact of violating these beliefs and codes on an organization, self, and others.
	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.

Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal.
	Coaching	Helping others learn new skills.
	Leadership	Communicating ideas to justify position; accepting responsibility for others; and encouraging, persuading, convincing, or otherwise motivating an individual or group.
	Negotiation	Resolving conflict between two or more individuals through discussion and compromise.
	Customer service	Working and communicating with customers to satisfy their expectations.
	Cultural diversity	Working well with men and women with a variety of ethnic, social, or educational backgrounds.
Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way.
	Interpretation	Selecting and analyzing information and communicating the results to others.
	Processing	Using computers to acquire, organize, analyze, and communicate information.
Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
	Monitoring	Distinguishing trends, predicting impact of actions on system operations, diagnosing deviations in systems' performance, and correcting malfunctions.
	Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems.
Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
	Application	Demonstrating proper procedures for setting up and operating equipment.
	Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.
Resources	Time	Selecting relevant, goal-related activities, ranking them in order of importance, allocating time, and understanding, preparing, and following schedules.
	Money	Using or preparing budgets, making forecasts, keeping records, and making adjustments to meet objectives.
	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Human resources	Accessing skills and distributing work accordingly; evaluating performance and providing feedback.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 1: Outboard-Engine Design and Identification			
Interpret outboard-engine labels (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Classify outboard-engine designs by their valve and cylinder arrangements (A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Complete outboard-engine information forms (A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Unit 2: Operation and Service of Engine-Support Systems			
Select the correct fuel and oil for outboard-engine applications (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
A.S. 1 (cont.)		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Determine parts and specifications for engine-support systems (A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Determine outboard-engine tune-up specifications and parts requirements (A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Interpret an outboard-engine troubleshooting chart (A.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
A.S. 4 (cont.)	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Fuel, start, operate, and shut down outboard engines (J.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform routine maintenance on fuel systems (J.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
J.S. 2 (cont.)	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair fuel systems (J.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
Perform routine maintenance on lubrication systems (J.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair lubrication systems (J.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy

Related Academic and Workplace Skills List

Unit 2: Operation and Service of Engine-Support Systems (cont.)

Task	Skill group	Subskill	Definition
J.S. 5 (cont.)		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform routine maintenance on cooling systems (J.S. 6)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair cooling systems (J.S. 7)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
J.S. 7 (cont.)	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform routine maintenance on ignition systems (J.S. 8)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment

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Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
J.S. 8 (cont.)		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair ignition systems (J.S. 9)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform routine maintenance on starting systems (J.S. 10)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
J.S. 10 (cont.)	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair starting systems (J.S. 11)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
Perform routine maintenance on charging systems (J.S. 12)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair charging systems (J.S. 13)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
J.S. 13 (cont.)		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform minor tune-ups (J.S. 14)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform major tune-ups (J.S. 15)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner

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Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
J.S. 15 (cont.)	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Troubleshoot failure-to-start in outboard engines (J.S. 16)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibilitv	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 2: Operation and Service of Engine-Support Systems (cont.)			
J.S. 16 (cont.)	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform failure analysis on outboard engines (J.S. 17)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Unit 3: Operation and Service of Power-Output Systems			
Determine parts and specifications for power-output systems (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 3: Operation and Service of Power-Output Systems (cont.)			
A.S. 1 (cont.)		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Interpret a power-output-system troubleshooting chart (A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Calculate gear ratios (A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
		Math	Performing basic computations
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Determine correct propeller characteristics for specific applications (A.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 3: Operation and Service of Power-Output Systems (cont.)			
A.S. 4 (cont.)	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Perform routine maintenance on power-output systems (J.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair power-output systems (J.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 3: Operation and Service of Power-Output Systems (cont.)			
J.S. 2 (cont.)	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Remove and replace propellers (J.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Check rpm on propellers (J.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task

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Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 3: Operation and Service of Power-Output Systems (cont.)			
J.S. 4 (cont.)		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform failure analysis on power-output-system components (J.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others

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Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 3: Operation and Service of Power-Output Systems (cont.)			
J.S. 5 (cont.)	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
J.S. 5 (cont.)		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Unit 4: Operation and Service of Control and Safety Systems			
Determine control-system and safety-system service specifications and parts requirements (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Perform routine maintenance on steering systems (J.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 4: Operation and Service of Control and Safety Systems (cont.)			
J.S. 2 (cont.)	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair steering systems (J.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform routine maintenance on tilt and trim systems (J.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 4: Operation and Service of Control and Safety Systems (cont.)			
J.S. 3 (cont.)	*Personal-management skills*	*Responsibility*	*Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration*
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair tilt and trim systems (J.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
Unit 4: Operation and Service of Control and Safety Systems (cont.)			
J.S. 4 (cont.)		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Perform routine maintenance on remote-control systems (J.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Repair remote-control systems (J.S. 6)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently

Related Academic and Workplace Skills List

Unit 4: Operation and Service of Control and Safety Systems (cont.)

Task	Skill group	Subskill	Definition
J.S. 6 (cont.)	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment
Service safety systems (J.S. 7)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a fact in written form in a clear, concise manner
	Thinking skills	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
	Personal-management skills	Responsibility	Working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how technology systems work and operate effectively
	Technology	Selection	Choosing procedures, tools, or equipment
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment

Outboard-Engine Design and Identification
Unit 1

Suggested Activities

Instructional plan

Preparation

- Review the unit in the student edition and plan your presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review the unit introduction and teaching suggestions included in the delivery and application section below, and plan classroom activities. Also note suggestions for media and supplemental materials.

  Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.

- Display equipment and illustrations that provide examples of various outboard engines in both two- and four-stroke-cycle designs in a wide range of sizes by different manufacturers.

- Make transparencies from the transparency masters included in the teacher pages of this unit.

- Select teacher components (teacher supplement, written test, unit evaluation form) you want to distribute to your students. Copy and prepare these components for distribution.

Delivery and application

Unit introduction

The skill areas appearing in bold-face type in the unit introduction and teaching suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want.* These have been adapted by MAVCC.

- Introduce yourself to the class and provide them with some information about your background and qualifications. Allow the students to introduce themselves, discuss their backgrounds, and explain why they are enrolled in the course.

  Discuss the course format, your policies, and the facility. Explain the concept of competency-based education and the design of the materials. If your students are familiar with your approach and with MAVCC materials from previous courses, tailor your explanation to their needs.

  Provide students with copies of the student materials. You may choose to begin by discussing the objective sheet. Review the unit and specific objectives with the students. Discuss how meeting the unit objective will improve their employability or will increase their value as an employee. Explain how the specific objectives support the unit objective. **(Listening; oral communication; adapting to the organization's**

traditional modes of operation; emphasizing personal and career development)

- Introduce the unit by discussing the fact that the course deals with outboard engines. Emphasize that the purpose of an engine is to provide power to a system—in this case, a boat system. If the students have studied other types of power product equipment, relate the outboard engine to other types of equipment that have engines, equipment drives, and drive trains. Use an actual engine to point out the power head, midsection, and lower unit and relate these sections to the engine and power-output components of other equipment with which the students may be familiar. Use various engine designs to emphasize similarities and differences in the three major sections of the outboard engine. Briefly discuss the support systems (starting, charging, cooling, lubricating, etc.) found on a typical outboard engine. Explain that this course will provide the students with training on how to service and repair outboard engines, including engine-support systems. If your course also covers the MAVCC companion materials on outboard-engine boat systems, discuss the use of those materials as a complement to this book. **(Listening; adapting to the organization's traditional modes of operation)**

Teaching suggestions

Objective 1 List the characteristics used to identify outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Use actual engines, service materials, and manufacturers' promotional brochures to introduce students to the important manufacturers. Emphasize those brands that are popular in your area. Use Student Supplement 1, "Outboard-Engine Manufacturer's Information," to acquaint students with various manufacturers. Discuss the present state of and trends in outboard-engine production, such as the mergers among manufacturers, the role of the Japanese and other foreign companies, etc. Use statistics from the National Marine Manufacturers Association to support this discussion. If available, have a manufacturer's representative discuss outboard-engine manufacturing with the class. If a manufacturing facility is nearby, visit the facility. Visit local retailers who sell outboard engines to expose the students to various brands popular in your area and to allow them to see local repair and service facilities, as many retailers will also provide service for their products. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; adapting to the organization's traditional modes of operation)**
- Using two or more engines, discuss other characteristics used to identify outboard engines. For example, have one four-stroke-cycle carbureted engine with one cylinder under 20 horsepower with a rope-rewind starter and a multiple-cylinder two-stroke-cycle fuel-injected engine over 200 horsepower with an electric starter and engines with different valve and cylinder arrangements. Discuss reasons for using various types of engines, including considerations such as power, boat

application, fuel efficiency, other resources available on the boat (a second battery, external fuel tank, etc.), and location of use (saltwater, cold regions, etc.). **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

- Expand the discussion by reviewing manufacturers' labels, the information provided, and how to interpret the labels and relate the information to service requirements. Use Supplement 1 as a guideline. Emphasize engines that are popular in your area. Show the students service manuals and parts catalogs that require the use of engine-label information, such as different service requirements based on date of manufacture or serial number. **(Listening; reading; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 2 State the purposes of the major sections of outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Use Transparency 1, "Major Sections and Major Components of Outboard Engines," and the actual engines you displayed for the first objective to point out the three major sections of outboard engines. Supplement the discussion with other engines and illustrations, models, etc. Point out similarities and differences in the design and construction of the three major sections, such as different standard heights of mid-sections, various water-tube designs, different locations for thermostats and water pumps, differences in water-intake and exhaust-port locations, etc. Relate the function of each section to other types of power product equipment. Introduce the next objective by pointing out the major components in each section. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**
- Use Student Supplement 2, "Outboard-Engine Construction," to expand the discussion or as self-study material to help students develop a deeper understanding of the major sections of the outboard engine. The supplement is particularly helpful at introducing students to the non-power-head components, which should be useful to students who are familiar with internal-combustion-engine design and operation but who are not familiar with outboard engines specifically. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 3 Match the major components of outboard engines to their correct functions.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Expand on your discussion of the previous objective and again use Transparency 1 and other illustrations and actual equipment to discuss the components of an outboard engine. Show a variety of each type of component, such as various power heads, varying throttle- and

steering-control designs, different types of mounting hardware, variations in lower-unit and propeller-assembly designs. Describe the function of each component as well as important operation, service, and safety considerations. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 4 Describe the combustion cycle of two-stroke-cycle outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use Transparency 2, "Combustion Cycle of Two-Stroke-Cycle Outboard Engines," to illustrate your discussion. Tailor the discussion in this and the next objective to match your students' familiarity with two- and four-stroke-cycle engine designs and operation. If your students are familiar with power product equipment engines, focus on differences in marine and land-based engines. If the students have not studied small engines and are not familiar with the two combustion cycles, spend time in helping them to grasp these concepts. Discuss what happens during each event. Describe different methods of delivering fuel to the combustion chamber. Provide examples of various types of valves used with two-stroke-cycle engines. Discuss the lubrication of two-stroke-cycle engines and methods of mixing oil with the fuel. Discuss scavenging methods. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 5 Describe the combustion cycle of four-stroke-cycle outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use Transparency 3, "Combustion Cycle of Four-Stroke-Cycle Outboard Engines," to illustrate your discussion. Approach the discussion of four-stroke-cycle engines in a manner similar to your presentation of two-stroke-cycle engines. Compare and contrast the events of the two types of engines. Discuss design variations required by the differences in operation, such as valves that open and close to expose or seal the combustion chamber and flat cylinder heads. Point out that some manufacturers refer to five combustion-cycle events for four-stroke-cycle engines, distinguishing between the ignition of the fuel/air mixture and the resulting movement of the piston as the power stroke. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 6 Complete statements that describe the major systems used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

Suggested Activities

- **Engine-support systems.** Again, if the students are familiar with small-engine design, relate your discussion of engine-support systems to concepts with which they are familiar. Help the students recognize similarities and differences between outboard-engine systems and other power product equipment engines. Guide the students in discussing why such differences exist. For example:

  — Why are most outboard engines water cooled while most other types of power product equipment are air cooled? (Because water is a more-efficient cooling agent but providing water cooling to land-based systems would require too much additional weight and complexity.)

  — Why do few outboard engines have mufflers and spark arrestors? (Because most port their exhaust below water level where combustion noises are muffled by the water and where exhaust gases and particles are not exposed to combustible materials.)

  — What engine-support system that is commonly found on power product equipment engines is missing from outboard engines? Why? (The governor system. Because marine engines face fewer changes in load that result from uneven terrain and varying power-output applications, such as when a lawnmower must be able to cut patches of thick grass among areas of thin grass.)

(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)

- **Power-output system.** Point out that outboard engines are integrated units that contain a means of transferring the power from the engine via the drive shaft to the propeller assembly. Compare these components to the power-transfer section of other types of power product equipment (belts, chains, driveshafts, etc.). If the students are inexperienced with power product equipment, try using automotive systems. Continue the comparison by relating the outboard-engine gearcase to the clutch and transmission systems and the propeller to the drive wheel. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

- **Control system.** Use an outboard engine with a tiller control to introduce types of control systems. It may be preferable to use an engine that has a starter switch on the tiller if one is available. In this way, steering, tilt, trim, throttle, and starting controls can be demonstrated. Once the students understand these concepts, discuss the equivalent remote systems, using actual equipment and boats to illustrate them. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

- **Safety system.** Discuss some of the dangers of operating a boat and describe safety systems that interface with the engine to improve boating safety. Use an actual boat and engine to demonstrate the operation of safety systems. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Suggested Activities

- Discuss typical service procedures associated with each type of system. Describe how these four types of systems (engine-support, power-output, control, and safety) provide a structure to the book and to the course. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 7 State applications for the types of pistons commonly used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use Transparency 4, "Types of Pistons Commonly Used in Outboard Engines," and provide actual examples of the various types of pistons to illustrate your discussion. Describe the purpose, operation, and application of different pistons in various types of engines. Point out that so-called "flat-head" pistons may not be level across the top, that they may be rounded to achieve specific characteristics (such as more power). Deflector-head pistons also exhibit variations in design, but each is constructed in such a way that it creates some division of the combustion chamber so that there is improved separation of the compression and exhaust events. Discuss specific engines that use various designs of pistons. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 8 List the types of valves commonly used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use Transparency 5, "Types of Valves Commonly Used in Outboard Engines," other illustrations, and actual equipment to provide examples of the various types of valves. Relate the designs to specific engines and particularly to combustion cycles. Describe the functions and operation of each type of valve used in your area. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 9 List the cylinder arrangements commonly used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use Transparency 6, "Cylinder Arrangements Commonly Used in Outboard Engines," to illustrate your discussion. Also provide engines that use the various types of cylinder arrangements. If the students are familiar with vertically oriented cylinders, point out that most outboard engines have horizontally oriented cylinders. Explain that even so, the portion of the engine that holds the spark plug is generally referred to as the *head*, the piston position nearest the spark plug is referred to as the *top of the stroke*, and camshafts and valves that are located in the head are referred to as *overhead valves* and *camshafts*. Emphasize cylinder designs that are popular in your region. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 10 List the valve arrangements commonly used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use Transparencies 7 through 9, other illustrations, and actual equipment to demonstrate the common valve arrangements used with outboard engines. Discuss types of engines that use each arrangement and the application of those engines. Use this opportunity to provide in-depth instruction on scavenging design for students who have not previously studied two-stroke-cycle engines. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Assignment Sheet 1 Interpret outboard-engine labels.

- Have students locate Assignment Sheet 1. Read the introduction and directions to the assignment. **(Reading/listening for direction)**

- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Listening, reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**

- Answer any student questions and have students complete Assignment Sheet 1.

Assignment Sheet 2 Classify outboard-engine designs by their valve and cylinder arrangements.

- Have students locate Assignment Sheet 2. Read the introduction and directions to the assignment. **(Reading/listening for direction)**

- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Listening, reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**

- Answer any student questions and have students complete Assignment Sheet 2.

Assignment Sheet 3 Complete outboard-engine information forms.

- Have students locate Assignment Sheet 3. Read the introduction and directions to the assignment. **(Reading/listening for direction)**

Suggested Activities

- Hand out extra copies of Teacher Supplement 1, "Engine-Information Form," as necessary. Make resources available that will allow the students to determine the required information on the engine-information form. Tailor the assignment sheet to equipment used in your facility. **(Listening, reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**
- Answer any student questions and have students complete Assignment Sheet 3.

Evaluation

- Evaluate the assignment sheets. See the evaluation criteria listed at the top of each assignment sheet as well as the teacher page "Answers to Assignment Sheets."
- Give the written test. See the teacher page "Written Test."
- Evaluate the written test. See the teacher page "Answers to Written Test."
- Compile written-test and assignment-sheet scores. See the teacher page "Unit Evaluation Form."
- Reteach and retest as required.

Suggested resources

Resources used in developing this unit

Print media

- Buchanan, George. *The Boat Repair Manual.* New York: Arco Publishing, Inc., 1985.
- *Everything You Need to Know About Propellers,* 4th ed. Brunswick Corporation, 1992.
- Gladstone, Bernard, and Tom Bottomley. *Boatkeeper: The Boatowner's Guide to Maintenance, Repair, and Improvement.* New York: Hearst Marine Books, 1984.
- Kendall, Dave. *The Complete Book of Boat Maintenance and Repair.* Garden City, New York: Doubleday and Company, Inc., 1975.
- Mercury Marine. Service manuals used in the development of this unit include:
  - — Accessories Parts Catalog, 1998.
  - — Service Manual, Models 135, 150, 175, 200, 225, September 1997.
  - — Service Manual, Models 9.9/15, 9.9/15 Bigfoot (4-Stroke), August 1998.
  - — Service Manual, Models 40, 50, 55, 60, January 1998.
  - — Service Manual, Models 4, 5 (4-Stroke), January 1999.
  - — Service Manual, Models V-300, V-3.4 Litre, 1984.

Suggested Activities

- Service Manual, Remote Controls, September 1998.
- Service Manual, Power Steering, 1996.

- Outboard Marine Corporation (OMC). Service manuals used in the development of this unit include:
  - 1999 EE 60° LV Service Manual
  - 1999 EE 90° LV Service Manual
  - 1999 EE 40 thru 70 Service Manual
  - 1999 EE 25, 35 Service Manual 3-Cylinder
  - 1999 EE 9.9 thru 30 Service Manual
  - 1999 EE 2 thru 8 Service Manual
  - 1999 EE 60° V4, V6 FFI Service Manual
  - 1999 EE 90° V6 FFI Service Manual
  - 1999 EE 70 4-Stroke Service Manual
  - 1999 EE 5 thru 15 4-Stroke Service Manual
  - 1999 EE Accessories Service Manual

- *Outboard Repair.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1985.

- *Parts Catalog: Model TOB-300.* Tanaka, 1998.

- Sherman, Edwin R. *Outboard Engines: Maintenance, Troubleshooting, and Repair.* Camden, Maine: International Marine, a division of The McGraw-Hill Companies, 1997.

- United States Coast Guard. *Skipper's Safe Boating Course,* 2nd ed. St. Louis, Missouri: Mosby-Year Book, Inc., 1996.

Suggested supplemental resources

Print media

- *Boating Magazine.* 1633 Broadway, New York, New York 10019, (212) 767-5585.

- *Motor Boating and Sailing* magazine. 250 W. 55th St., New York, New York 10019, (212) 649-4099.

- *Trailer Boats.* Poole Publications, Inc., 20700 Belshaw Ave., Carson, California 90746-3510, (310) 537-6322.

- Service manuals for systems covered in this unit. Available from equipment manufacturers.

- Parts catalogs for systems covered in this unit. Available from equipment manufacturers.

Suggested Activities

Nonprint media

- Small-engine video series. Each of these 15-minute VHS programs covers the title topics and carry 1993 and 1994 copyrights. The first program includes information about outboard engines, as well as other types of power product equipment. The remaining programs use Briggs and Stratton 3- and 5-hp engines as examples, but of course, many of the principles apply to outboard engines. The videotapes are available from Shopware, P.O. Box 2708, Charleston, West Virginia 25330, (800) 487-3392. Available titles include:
  - The Basics
  - Four-Stroke-Engine Operation
  - Engine Disassembly
  - Engine Reassembly
  - Completing the Reassembly
  - Fuel-System Diagnosis
  - Ignition-System Diagnosis
  - Systems Diagnosis
  - Maintenance and Storage
  - Two-Stroke-Engine Operation
  - Two-Stroke-Engine Disassembly
  - Two-Stroke-Engine Assembly
  - Two-Cycle-Engine Troubleshooting
  - Servicing and Storing Two-Cycle Engines

- *Outboard Motors.* This VHS program discusses safety in outboard-engine operation as well as maintenance for the power head and lower unit. Available from Shopware.

- *Multimedia Small Engines.* These 1998 CD-ROM programs come in three parts that combine video, animation, text, and photos to discuss operation and service of small engines for computers running Windows. The first program covers engine design and the ignition system. The second program discusses lubrication, cooling, speed control, and fuel systems. The final program focuses on fault diagnosis and overhaul. Available from Shopware.

Organizations

- National Marine Manufacturers Association. A good source of information about trends in watercraft sales and production. 200 E. Randolph Drive, Suite 5100, Chicago, Illinois 60601, (312) 946-6200, website http://www.nmma.com.

- Association of Marine Technicians (AMTECH). An organization dedicated to improving marine service through cooperation, certification, and education. 455 Knollwood Terrace, Roswell, Georgia 30075-3416, (800) 467-0982.

Outboard-Engine Design and Identification
Unit 1

Answers to Assignment Sheets

Assignment Sheet 1—The correct answers will vary depending on the specific engine referenced, and may vary depending on model year, serial number, emissions equipment, engine configuration, intended application, and other factors. Instructors should accept answers based on the reference materials available to the students.

Assignment Sheet 2—The correct answers will vary depending on the specific engine referenced, and may vary depending on model year, serial number, emissions equipment, engine configuration, intended application, and other factors. Instructors should accept answers based on the reference materials available to the students.

Assignment Sheet 3—The correct answers will vary depending on the specific engine referenced, and may vary depending on model year, serial number, emissions equipment, engine configuration, intended application, and other factors. Instructors should accept answers based on the reference materials available to the students.

Outboard-Engine Design and Identification
Unit 1

Answers to Written Test

1. Answers may appear in any order.

    - Manufacturer
    - Horsepower
    - Combustion cycle
    - Engine-support-system characteristics
    - Cylinder number
    - Cylinder displacement
    - Cylinder arrangement
    - Valve arrangement

2. a. Houses the engine and produces the power to drive a boat

    b. Joins the power head to the lower unit and provides a means of mounting the engine to the boat

    c. Converts the power output of an engine into a driving force in the propeller

3. a. 10
    b. 15
    c. 4
    d. 13
    e. 12
    f. 1
    g. 5
    h. 9
    i. 6
    j. 2
    k. 11
    l. 14
    m. 16
    n. 3
    o. 7
    p. 8

4. a. The piston completes its movement toward the crankcase, opening the transfer port and allowing the fuel/air mixture to enter the combustion chamber.

    b. The piston moves toward the combustion chamber, covering the transfer and exhaust ports and compressing the fuel/air mixture.

    c. The piston completes its movement toward the combustion chamber, and the intake port closes, sealing the fuel/air mixture in the crankcase; simultaneously, a spark at the spark plug ignites the compressed fuel/air mixture.

    d. The piston is forced away from the combustion chamber, causing the crankshaft to turn; as the piston moves away from the combustion chamber, the exhaust port opens, allowing exhaust gases to escape from the combustion chamber; this also opens the transfer port for the beginning of the next intake event, and the entering fuel/air mixture helps to scavenge the exhaust gases.

5. a. The piston moves away from the combustion chamber with the exhaust valve closed and the intake valve open, pulling fuel/air mixture into the combustion chamber.

    b. The piston moves toward the combustion chamber with both valves closed, compressing the fuel/air mixture.

Answers to Written Test

c. With both valves closed, a spark at the spark plug ignites the compressed fuel/air mixture, forcing the piston away from the combustion chamber, which rotates the crankshaft.

d. The piston moves toward the combustion chamber with the intake valve closed and the external valve open, forcing exhaust gases from the combustion chamber.

6. a. **Engine-support systems**

Fuel system
1) combustion chamber
2) diaphragm; gravity feed

Lubrication system
3) two
4) four
5) crankcase bleed

Cooling system
6) heat
7) water
8) pump
9) engine coverings

Ignition system
10) spark
11) ignition modules; spark plugs

Starting system
12) flywheel
13) rope-rewind; electric
14) electric
15) electrical

Charging system
16) battery; electrical

Exhaust system
17) unburned; combustion
18) water level
19) water

b. **Power-output system**
1) engine
2) integrated
3) crankshaft; propeller shaft
4) propeller

c. **Control system**
1) operation; position
2) tiller; remote controls
3) horizontally; vertically
4) remote controls

d. **Safety system**
1) equipment; injury
2) engine; engine-support; control
3) tilt switches, neutral safety switches; emergency-stop lanyards; revolution limiters

Answers to Written Test

7. a. Commonly used in four-stroke-cycle engines

   b. Commonly used in two-stroke-cycle engines in which they serve to improve compression and exhaust removal, but are also found in four-stroke-cycle engines

8. Answers may appear in any order.

   - Reed valve
   - Rotary valve
   - Stem valve

9. Answers may appear in any order.

   - In-line cylinder arrangement
   - V-type cylinder arrangement

10. Answers may appear in any order.

   - I-head arrangement
   - Valves set at an angle to each other
   - Cross-scavenged
   - Loop-scavenged

Outboard-Engine Design and Identification
Unit 1

Written Test

Name ______________________________ Score ______________

1. List the characteristics used to identify outboard engines. Write your answers on the blank lines provided below.

   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________
   e. ______________________________
   f. ______________________________
   g. ______________________________
   h. ______________________________

2. State the purposes of the major sections of outboard engines. Write your answers on the blanks provided beside the terms below.

   a. Power head ______________________________
   ____
   ____
   ____

   b. Midsection ______________________________
   ____
   ____
   ____

   c. Lower unit ______________________________
   ____
   ____
   ____

Written Test

3. Match the major components of outboard engines to their correct functions. Write the numbers on the blanks.

_______ a. Picks up water and moves it through the cooling system

_______ b. Moves water from one side of its blades to the other to create the movement of the boat

_______ c. Allows the circulation of water around the engine to remove heat

_______ d. Provides an intake port for the cooling-system water

_______ e. Allows water from the cooling system and exhaust gases from the engine to exit the engine

_______ f. Produces the power to drive a boat

_______ g. Controls the direction of coolant flow based on engine temperature

_______ h. Changes the gear relationships to allow forward or reverse movement of the boat

_______ i. Protects the engine from the environment

_______ j. Adjusts the fuel/air mixture to regulate engine speed

_______ k. Separates the submerged and above-water portions of the engine

_______ l. Houses the gears that transmit power from the drive shaft to the propeller

_______ m. Improves steering, helps provide more-even water flow past the propeller, and protects the propeller

_______ n. Turns the engine flywheel to begin the internal-combustion process

_______ o. Allows the engine to be installed on a boat

_______ p. Transfers the rotary power from the engine to the gearcase

1. Engine
2. Throttle control
3. Starter
4. Water jacket
5. Thermostat
6. Housing
7. Mounting hardware
8. Drive shaft
9. Shift rod
10. Water pump
11. Antiventilation plate
12. Exhaust port
13. Water inlet
14. Gearcase
15. Propeller
16. Skeg

Written Test

4. Describe the combustion cycle of two-stroke-cycle outboard engines. Write your answers on the blank lines provided beside the terms below.

Intake/compression stroke

a. Intake event ______________________

b. Compression event ______________________

Power/exhaust stroke

c. Power event ______________________

d. Exhaust event ______________________

5. Describe the combustion cycle of four-stroke-cycle outboard engines. Write your answers on the blank lines provided beside the terms below.

   a. Intake stroke ____________________

   b. Compression stroke ____________________

   c. Power stroke ____________________

   d. Exhaust stroke ____________________

6. Complete statements that describe the major systems used in outboard engines. Write your answers on the blanks provided in the statements below and on the next pages.

   a. **Engine-support systems**

   Fuel system

   1) The fuel system mixes fuel with air and delivers it to the ____________________.

   2) Most outboard engines use either a ____________________ fuel pump or a ____________________ assisted by the low-pressure suction created in the crankcase during the internal-combustion process.

Written Test

Lubrication system

3) Most outboard engines are ____________________-stroke-cycle engines, which means that lubrication is achieved by mixing oil with the fuel.

4) ____________________-stroke-cycle engines use oil slingers or pump systems to circulate lubricant.

5) Some multiple-cylinder engines include a ______________________________ system to return unburned oil to the cylinders, bearings, or other components to supplement the main lubrication system.

Cooling system

6) The cooling system helps remove ____________________ from the engine.

7) Most outboard engines are ____________________ cooled.

8) The cooling system includes a ____________________ that pulls water into the engine and passes it over heated parts.

9) While some air cooling takes place, the cooling effect of this air is limited by the ______________________________ that are designed to reduce the engine's exposure to water.

Ignition system

10) The ignition system provides the ____________________ that ignites the fuel/air mixture.

11) Because of the high humidity of the operating environment of outboard engines, ______________________________ and ______________________________ may have special characteristics when compared to those used in other types of power product equipment.

Starting system

12) The starting system turns the ____________________ to begin the internal-combustion cycle.

Written Test

13) Some outboard engines have ____________________ starters, many are equipped with ____________________ starters, and some are equipped with both types of starters.

14) A battery is used to power ____________________ starters.

15) The battery may also be used to power some ____________________ systems, such as running lights, especially when the engine is not running.

Charging system

16) The charging system produces electricity to maintain a level of electrical charge in the ____________________ and to power select ____________________ circuits.

Exhaust system

17) The exhaust system removes ____________________ fuel and ____________________ gases from the engine.

18) Though some outboard engines include mufflers, most route the exhaust gases to exit the engine below the ____________________.

19) Most outboard engines also mix ____________________ from the cooling system with exhaust gases to provide additional cooling.

b. Power-output system

1) The components of the power-output system transmit the power from the ____________________ to a point where work is done.

2) Unlike most types of power product equipment, the power-output system is ____________________ in outboard engines.

3) The power-output system in an outboard engine consists of an extension to the ____________________, which serves as the drive shaft and passes through the midsection to mesh with the gearcase. The gears drive the ____________________, which in turn powers the propeller.

Written Test

4) The ____________________ is the point where work is done; it provides the thrust that drives the boat, much like the drive wheels on self-powered equipment.

c. **Control system**

1) The control system allows the operator to adjust different aspects of the engine's ____________________ or ____________________, such as engine speed, the direction of propeller rotation, the gearcase setting, tilt, trim, and other performance features.

2) Control-system devices are generally located in one of two places on boats with outboard engines: on the ____________________ or ____________________.

3) The most-common type of control, especially on smaller engines, is called a *tiller.* A tiller is simply a handle that protrudes from the engine and allows the boat operator to pivot the engine ____________________. Tiller handles also usually allow the operator to tilt the engine ____________________. Some tiller handles include controls for throttle settings, operating an electric starter, tilt and trim, or other functions.

4) Controls located at places other than the tiller are referred to as ______________________________ and include steering systems, throttle handles, gearcase shift levers, starter switches, power tilt-and-trim controls, and other functional controls.

d. **Safety system**

1) The safety-system devices prevent the operation of the engine or boat system during conditions when such operation might result in ____________________ damage or ____________________.

2) In outboard engines, safety-system devices may be installed on the ____________________ itself, in some ______________________________ system, or in the ____________________ system.

3) Common safety devices include ______________ that cut off the flow of fuel if the boat is at a dangerous angle, ______________ that will not allow the engine to start if the gears are engaged, ______________ that stop the engine if the operator of the boat is too far from the control area, ______________ to prevent engine overspeed, and others.

7. State applications for the types of pistons commonly used in outboard engines. Write your answers on the blank lines provided beside the terms below.

   a. Flat-head pistons ______________

   ____

   ____

   ____

   ____

   b. Deflector-head pistons ______________

   ____

   ____

   ____

   ____

8. List the types of valves commonly used in outboard engines. Write your answers on the blank lines provided below.

   a. ______________

   b. ______________

   c. ______________

9. List the cylinder arrangements commonly used in outboard engines. Write your answers on the blank lines provided below.

   a. ______________

   b. ______________

Written Test

10. List the valve arrangements commonly used in outboard engines. Write your answers on the blank lines provided below.

    a. ____________________

    b. ____________________

    c. ____________________

    d. ____________________

Permission to duplicate this test is granted.

Outboard-Engine Design and Identification
Unit 1

Unit Evaluation Form

Student name ______________________ Unit rating ____________

Assignment-sheet ratings

Assignment Sheet 1—Interpret Outboard-Engine Labels Rating ________

Comments: ____

____

Assignment Sheet 2—Classify Outboard-Engine Designs by Their Valve and Cylinder Arrangements Rating ________

Comments: ____

____

Assignment Sheet 3—Complete Outboard-Engine Information Forms Rating ________

Comments: ____

____

Written-test scores

Pretest ________ Posttest ________ Other ________

Comments: ____

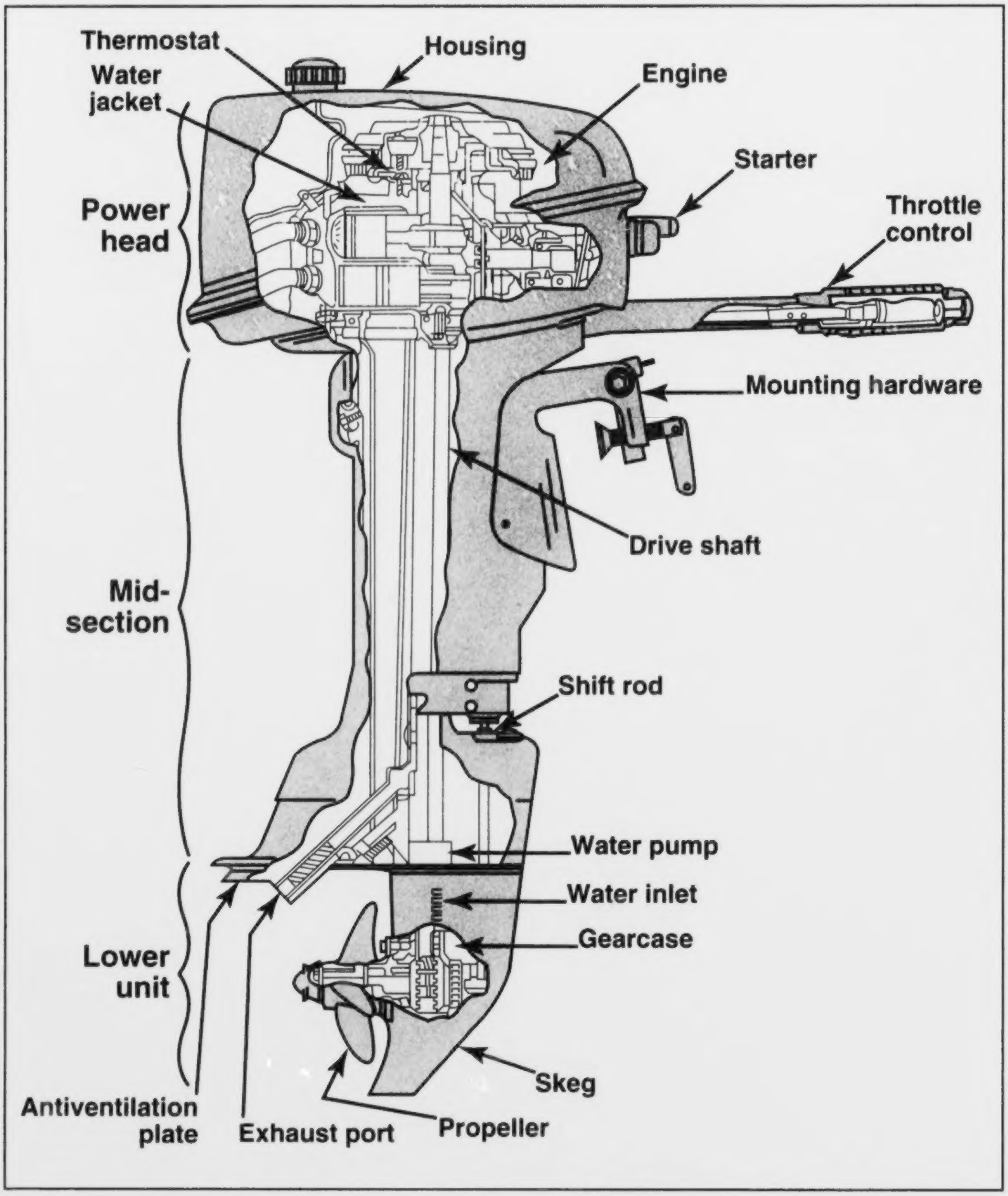
____

Teacher signature ______________________ Date ____________

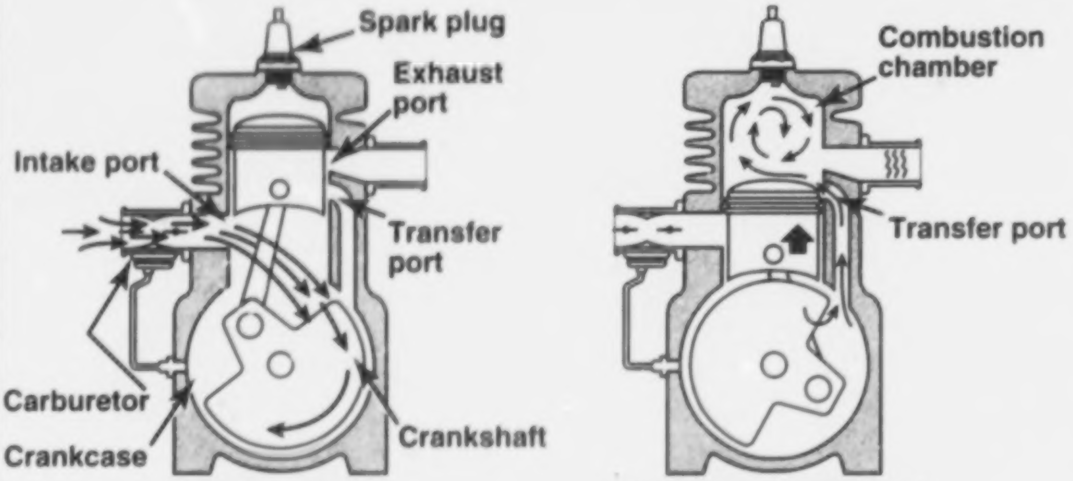
Student signature ______________________ Date ____________

Permission to duplicate this form is granted.

Major Sections and Major Components of Outboard Engines


Thermostat
Housing
Water jacket
Engine
Starter
Power head
Throttle control
Mounting hardware
Drive shaft
Mid-section
Shift rod
Water pump
Water inlet
Gearcase
Lower unit
Skeg
Antiventilation plate
Exhaust port
Propeller

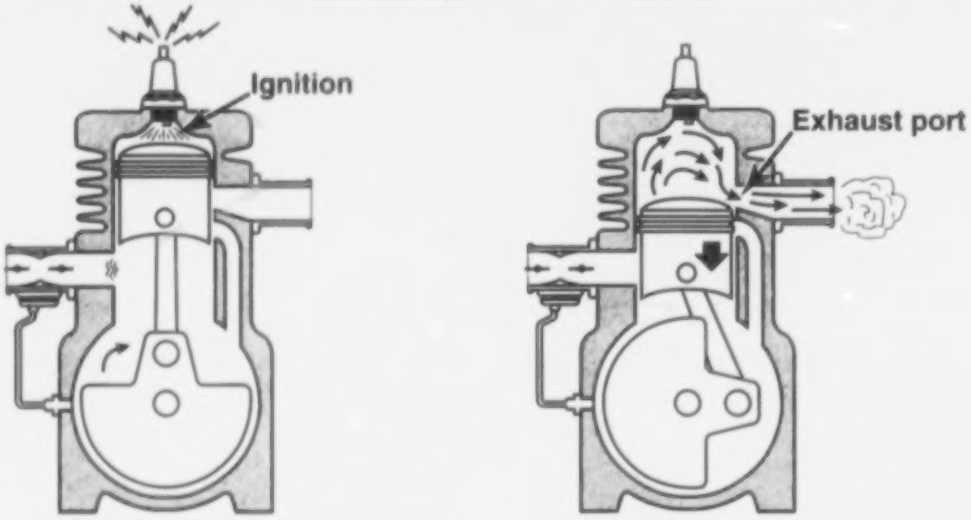
Combustion Cycle of Two-Stroke-Cycle Outboard Engines


Spark plug
Exhaust port
Intake port
Transfer port
Carburetor
Crankcase
Crankshaft
Combustion chamber
Transfer port

Intake event

Compression event

1. Intake/compression stroke


Ignition
Exhaust port

Power event

Exhaust event

2. Power/exhaust stroke

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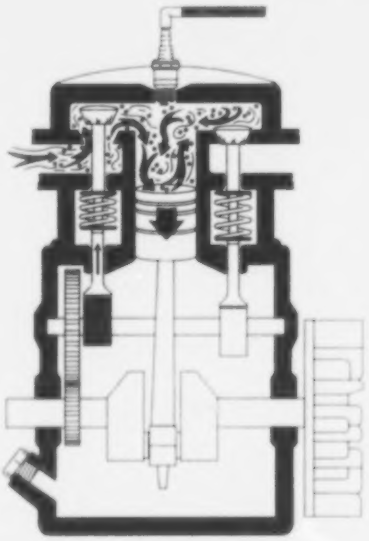
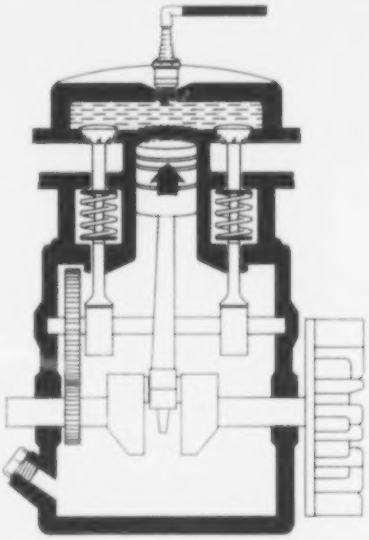
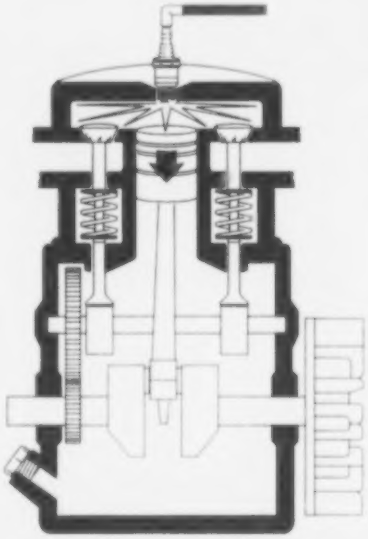
Combustion Cycle of Four-Stroke-Cycle Outboard Engines



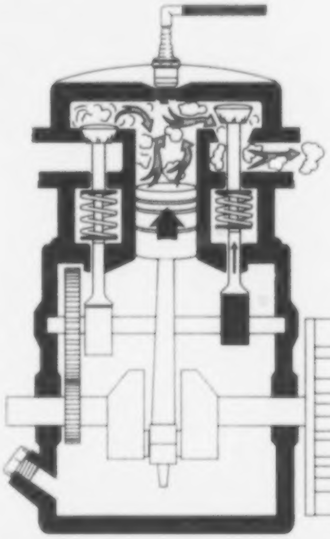
1. Intake stroke



2. Compression stroke

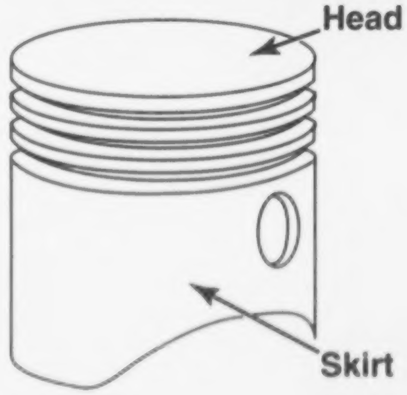


3. Power stroke

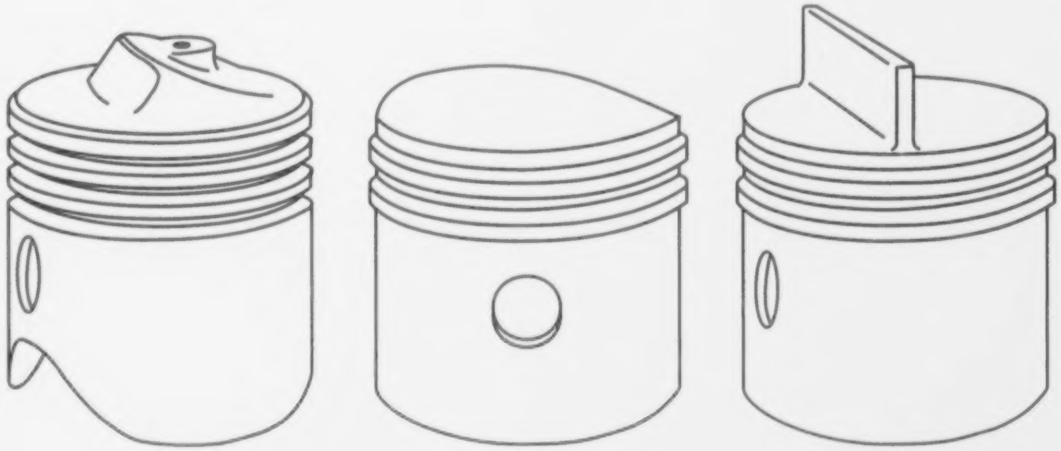


4. Exhaust stroke

Types of Pistons Commonly Used in Outboard Engines

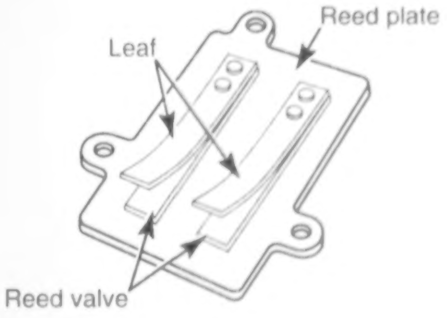


Flat-head piston (standard piston)

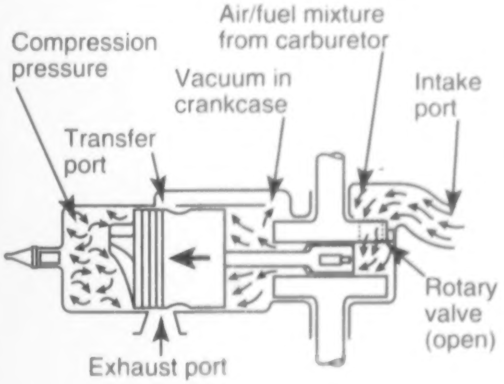


Deflector-head pistons

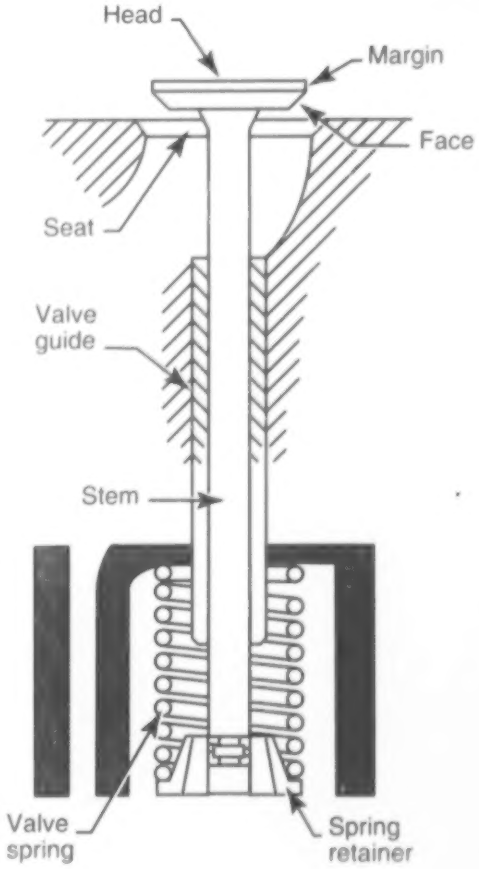
Types of Valves Commonly Used in Outboard Engines


Reed plate
Leaf
Reed valve

Reed valve

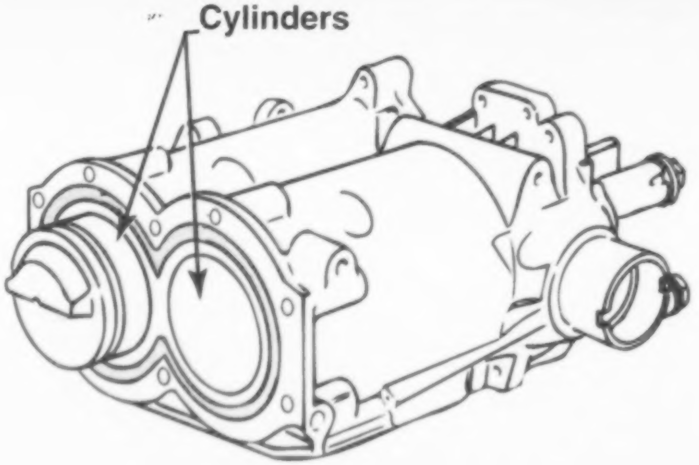

Air/fuel mixture from carburetor
Compression pressure
Vacuum in crankcase
Intake port
Transfer port
Rotary valve (open)
Exhaust port

Rotary valve

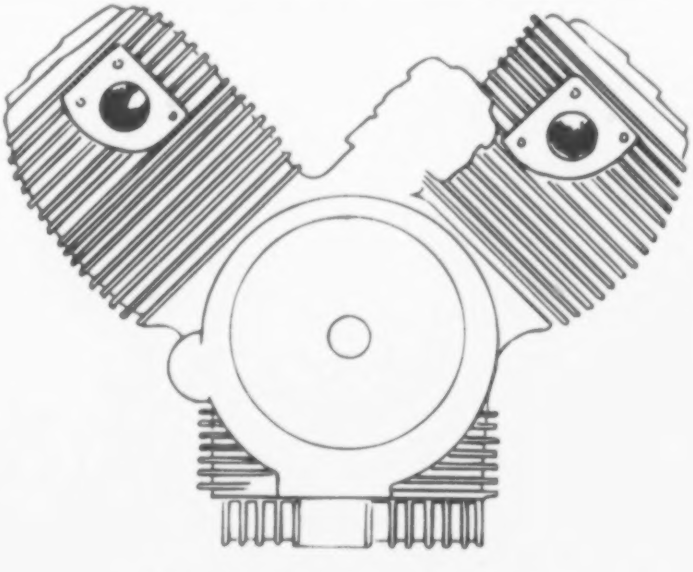

Head
Margin
Face
Seat
Valve guide
Stem
Valve spring
Spring retainer

Stem valve

Cylinder Arrangements Commonly Used in Outboard Engines



In-line arrangement



V-type arrangement

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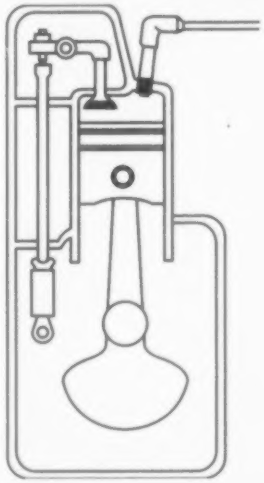
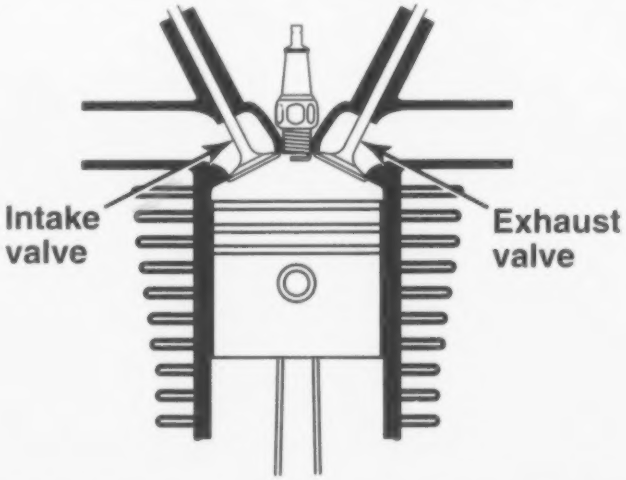
TM 6

Valve Arrangements Commonly Used in Outboard Engines:

Overhead-Valve Arrangements



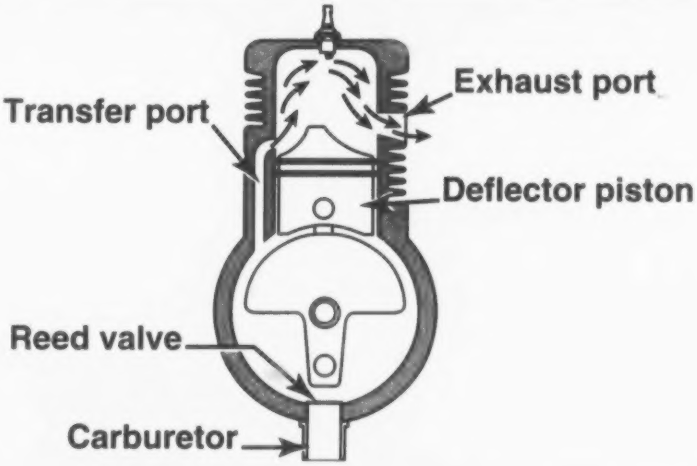
I-head arrangement


Intake
valve
Exhaust
valve

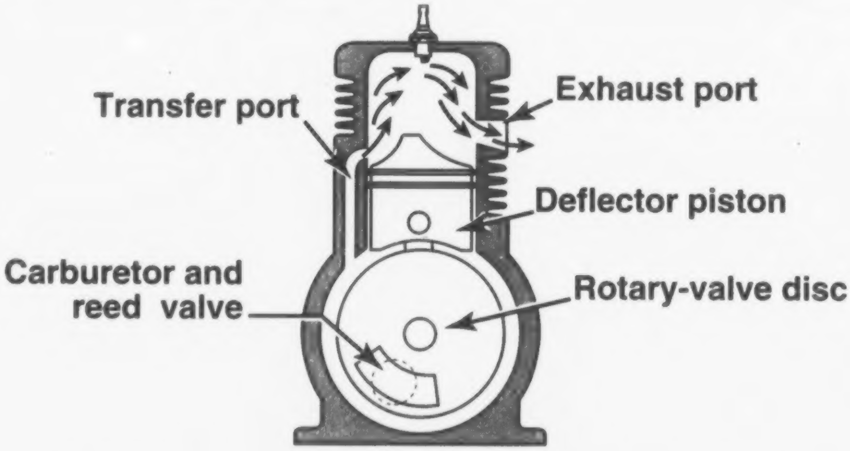
Valves set at an angle to each other

Valve Arrangements Commonly Used in Outboard Engines:

Cross-Scavenged Designs


Transfer port
Exhaust port
Deflector piston
Reed valve
Carburetor

Cross-scavenged with reed valve


Transfer port
Exhaust port
Deflector piston
Carburetor and reed valve
Rotary-valve disc

Cross-scavenged with rotary valve

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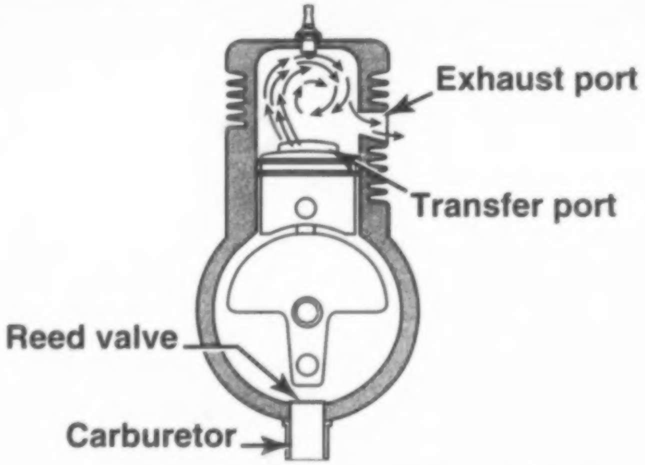
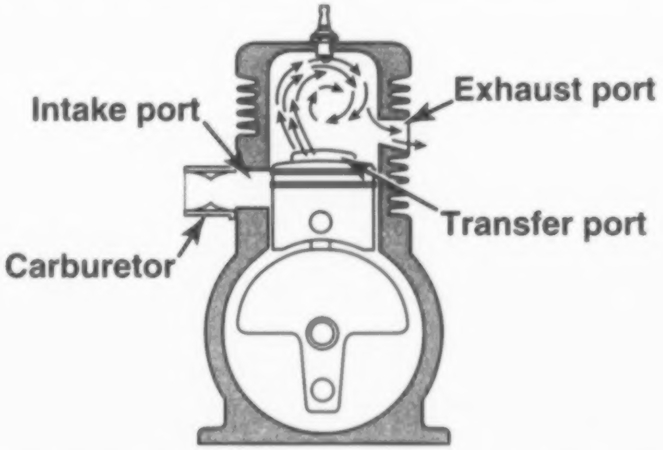
Valve Arrangements Commonly Used in Outboard Engines:

Loop-Scavenged Designs


Exhaust port
Transfer port
Reed valve
Carburetor

Loop-scavenged with reed valve


Intake port
Exhaust port
Transfer port
Carburetor

Loop-scavenged with piston-controlled third port

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Outboard-Engine Design and Identification
Unit 1

Teacher Supplement 1—Master for Engine-Information Form

Note: Use the engine-information form on the next page as a master for making photocopies of the form students are to use in completing Assignment Sheet 3, "Complete Outboard-Engine Information Forms."

Engine-Information Form

Dealer's name ______________________________

Dealer's address ______________________________

Owner's name ______________________________

Technician's name ______________________________

Serial number ______________ Model number ______________

Horsepower/kw ______________ Date of manufacture ______________

Date of purchase ______________ Approximate hours used __________

Displacement (cu. in./liters) __________ Fuel injection: ☐ Yes ☐ No

Two-stroke-cycle engine ☐ Four-stroke-cycle engine ☐

Manual start ☐ Electric start ☐

Oil injection ☐ Power trim ☐

Number of cylinders ______________

Recommended idle rpm ______________

Recommended fuel ______________

Recommended oil ______________

Comments:

____

____

____

____

____

Operation and Service of Engine-Support Systems
Unit 2

Suggested Activities

Instructional plan

Preparation

- Review the unit in the student edition and plan your presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review the unit introduction and teaching suggestions included in the delivery and application section below, and plan classroom activities. Also note suggestions for media and supplemental materials.

  Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.

- Display equipment, tools, and illustrations that will help students understand engine-support systems and related service more fully.
- Select teacher components (written test, unit evaluation form) you want to distribute to your students. Copy and prepare these components for distribution.
- Review the job sheets and worksheets in the student edition and locate the worksheet masters included in the teacher pages of this unit. Copy and prepare extra worksheets for distribution to your students.

Delivery and application

Unit introduction

The skill areas appearing in bold-face type in the unit introduction and teaching suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want*. These have been adapted by MAVCC.

- Provide students with copies of the student materials. You may choose to begin by discussing the objective sheet. Review the unit and specific objectives with the students. Discuss how meeting the unit objective will improve their employability or will increase their value as an employee. Explain how the specific objectives support the unit objective. **(Listening; adapting to the organization's traditional modes of operation; emphasizing personal and career development)**
- Introduce the unit by discussing the internal-combustion process as described in the previous unit. Lead the students in a discussion of how power is produced in the engine and how the products and by-products of that process are handled. For example, some force must be applied to the engine to start the combustion cycle (the starting system). Fuel and air must be mixed and delivered to the combustion chamber to provide a source of combustion energy (the fuel system). A spark is required to ignite the fuel/air mixture (the ignition system). The gases produced by the ignition process must be moved from the engine (the

exhaust system). To prevent damage to the engine from friction and overheating, the moving parts must be lubricated (the lubrication system) and cooled (the cooling system). Point out that a problem with any of these systems could prevent the engine from working efficiently and might prevent it from working at all. Further, explain that even when the systems are working correctly, a failure could occur if the systems are not properly synchronized or maintained, such as having the incorrect fuel/oil ratio in a two-stroke-cycle engine. State that the purpose of this unit is to help the students understand the operation of engine-support systems and how to properly service them. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Teaching suggestions

Objective 1 Define the term *engine-support system.*

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Use your discussion in the unit introduction to help the students come to a definition of an engine-support system. Guide the discussion to cover the points made in the information sheet or use a definition developed by the students if it is more appropriate for your program. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information)**

Objective 2 List the major engine-support systems used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Use an actual engine, model, or illustrations to build on your discussion in Objective 6 of Unit 1, which covered the various engine-support systems. Keep the discussion brief, as specific information will be covered in the subsequent objectives in this unit. Use the unit and specific objectives to help the students understand that the remaining objectives reinforce the list given in this objective. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 3 Complete statements that describe the typical fuel systems used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Use actual equipment or illustrations to discuss the design and functioning of typical components of an outboard-engine fuel system. Show examples of both carbureted and fuel-injection systems. Discuss these systems in the detail required as a result of your students' instructional background. If additional resources are required, refer to MAVCC's *Power Product Equipment Technician: Engine Systems and*

Service, Unit 3, "Fuel Systems." Emphasize the differences in marine systems, such as external fuel tanks and water-separating filters. Ensure that students understand the concept of metering and its role in proper engine operation. Discuss service requirements required for fuel systems and symptoms of improper operation. Emphasize safety precautions related to fuel systems and the handling of gasoline and other fuels. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 4 Match types of fuels used in outboard engines to their correct applications.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Focus your discussion on the types of outboard-engine fuels to those fuels typically used in your area and provide the students with information about the reasons for such regional preferences. Discuss blended fuels and fuel additives. Provide the students with engine manufacturers' service materials related to fuels for outboard engines and their applications in your area. Explain octane ratings as presented by fuel retailers and relate these ratings to the octane requirements provided by engine manufacturers. Discuss the effects of aging and storage on fuels, as well as likely sources of fuel contamination in the marine environment. Describe the operation and efficiency of various types of filtration systems for specific applications. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 5 Describe the factors considered in the design of outboard-engine fuel tanks.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Display various types of marine fuel tanks (including engine-mounted tanks) and point out features of their design and construction. Relate these features to the factors presented in the information sheet. Provide the students with examples of rusty or corroded fuel tanks and fuel tanks that have been damaged due to poor installation or improper service. Display systems with entrapped contaminants and sediments, as well as fuel injectors and carburetors that have been damaged by contaminated fuel. Demonstrate the importance of venting by showing the difference between liquid poured from a gasoline container without the vent cap removed and with the vent cap removed, perhaps using water for increased safety. Explain the physical principles behind the demonstration and what would happen to an engine or fuel tank if venting was not provided. Demonstrate the use of various types of primer, choke, and enrichment systems; explain their operation and purpose. **(Listening; reasoning; science; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 6 List probable causes of fuel-system problems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Review the operation of both carbureted and fuel-injected engines with regard to fuel delivery and relate the steps of this process to the listed fuel-system problems. Provide the students with examples of the problems listed. For example, show a cross-sectional cutaway of a clogged fuel line or filter. Demonstrate how mechanical linkages can bind. Display fuel pumps with weak and ruptured diaphragms. Use service manuals to discuss float settings and needle-valve settings. Use a troubleshooting chart such as that provided in Assignment Sheet 4, "Interpret an Outboard-Engine Troubleshooting Chart," to discuss fuel-system problems and likely symptoms. Emphasize the need for clean, properly mixed fuel. Describe and demonstrate related service procedures. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 7 Complete statements that describe the typical lubrication systems used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use actual equipment or illustrations to discuss the design and functioning of typical components of an outboard-engine lubrication system. Show examples of both pressure lubrication systems and lubrication by mixing oil with the fuel either manually or by oil injection. Discuss these systems in the detail required as a result of your students' instructional background. If additional resources are required, refer to MAVCC's *Power Product Equipment Technician: Engine Systems and Service,* Unit 1, "Lubrication Systems." Emphasize the differences in marine systems, such as lubricating oils formulated specifically for marine applications and marine-grade oil filters. Ensure that students understand the concept of oil-mixture ratios and the role the proper oil-mixture ratio plays in engine operation. Discuss service requirements for lubrication systems and symptoms of improper operation. Emphasize safety precautions related to lubrication. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 8 Complete statements that describe the typical cooling systems used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use actual equipment or illustrations to discuss the design and functioning of typical components of an outboard-engine cooling system. Show examples of both pressure- and volume-type pump systems, as well as a variety of intake and exhaust-port designs, pump locations, and thermostat locations. Discuss these systems in the detail required as a result of your students' instructional background. If additional resources are required, refer to MAVCC's *Power Product Equipment Technician: Engine Systems and Service*, Unit 2, "Cooling Systems." Emphasize the differences in marine systems, such as the more-common use of water-cooled engines. Point out that air cooling is still part of the outboard-engine design and explain the importance of keeping the engine clean and free of corrosion and "fouling." Ensure that students understand the operation of thermostats and their role in proper engine operation. You may wish to demonstrate testing a thermostat even if you do not teach the procedure as a service requirement. Discuss service requirements required for cooling systems and symptoms of improper operation. Emphasize safety precautions related to cooling systems and the handling of overheated engines and hot cooling-system components. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 9 Describe the types of water pumps commonly used in outboard-engine cooling systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use actual equipment, models, and illustrations to discuss the two types of water pumps. Provide students with examples of engines that use each type and discuss why one may be preferable over the other for specific applications. Explain how displacement occurs in the pump as the impellers move within the pump body. If the students have studied power product equipment pumps, relate the operation of outboard-engine water pumps to other concepts that they have studied. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 10 Complete statements about the principles of operation of volume-type water pumps.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Build on your discussion of general pump operation to discuss the specifics of volume-type pump operation. Discuss failures that can occur and normal maintenance procedures. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 11 Complete statements about the principles of operation of pressure-type water pumps.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Build on your discussion of general pump operation to discuss the specifics of pressure-type pump operation. Compare and contrast pressure-type pump operation with volume-type pump operation.

Suggested Activities

Discuss failures that can occur and normal maintenance procedures. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 12 Complete statements about the principles of operation of outboard-engine ignition systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use actual equipment or illustrations to discuss the design and functioning of typical components of an outboard-engine ignition system. Show examples of each type of ignition system covered in your course, including breaker, solid-state, and digital systems. Discuss these systems in the detail required as a result of your students' instructional background. If additional resources are required, refer to MAVCC's *Power Product Equipment Technician: Engine Systems and Service*, Unit 6, "Ignition Systems." Emphasize specific concepts, such as silicon-controlled rectifiers and coil principles, as required by your course objectives. Ensure that students understand the concept of charge buildup in order to obtain sufficient spark with a minimum of input current. Discuss service requirements required for ignition systems and symptoms of improper operation. Emphasize safety precautions related to ignition systems. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 13 Match types of tests performed on outboard-engine ignition systems to their correct purposes. **Objective 14** Match tools and instruments used to test ignition systems to their correct purposes.

- Read and discuss with students the information presented in these sections of the information sheet. **(Reading/listening for content)**

- Demonstrate the operation of each tool and instrument used in your facility to test ignition systems. Provide the students with service manuals that require the use of such equipment. Allow students to practice setting up, connecting, and adjusting the equipment. Discuss precautions to observe during the use of such equipment. Use this opportunity to discuss other types of equipment used in conjunction with engine-support systems. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 15 List probable causes of ignition-system problems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Review the operation of the various types of ignition systems with regard to spark delivery, and relate the steps of this process to the listed ignition-system problems. Provide the students with examples of the problems listed. For example, show fouled spark plugs, pitted breakers, worn cams, etc. Use service manuals to discuss gap settings and timing adjustments. Use a troubleshooting chart such as that provided in Assignment Sheet 4, "Interpret an Outboard-Engine Troubleshooting Chart," to discuss ignition-system problems and likely symptoms. Describe and demonstrate related service procedures. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 16 Complete statements that describe the typical starting systems used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use actual equipment or illustrations to discuss the design and functioning of typical components of an outboard-engine starting system. Show examples of both manual and electrical starting systems. Discuss these systems in the detail required as a result of your students' instructional background. If additional resources are required, refer to MAVCC's *Power Product Equipment Technician: Engine Systems and Service*, Unit 7, "Starting Systems." Emphasize the differences in marine systems, such as starter switches on the tiller versus dash systems or dedicated battery systems. Discuss service requirements required for starting systems and symptoms of improper operation. Emphasize safety precautions related to starting systems and the handling of batteries. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 17 Complete statements that describe the typical charging systems used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use actual equipment or illustrations to discuss the design and functioning of typical components of an outboard-engine charging system. Show examples of both stator- and belt-driven alternator systems. Discuss these systems in the detail required as a result of your students' instructional background. If additional resources are required, refer to MAVCC's *Power Product Equipment Technician: Engine Systems and Service*, Unit 8, "Charging Systems." Emphasize the differences in marine systems, such as battery isolators and multiple batteries. Ensure that students understand the concepts behind various related components such as solenoids, voltage regulators, circuit protectors, etc. Discuss service requirements for charging systems and symptoms of improper operation. Emphasize safety precautions related to charging systems and the handling of batteries. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Suggested Activities

Objective 18 State the purpose of battery isolators.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Continue your discussion of charging systems by explaining the purpose of battery isolators. Discuss boat electrical systems, grounding principles, galvanic protection, and related concepts. Display a variety of battery-isolator circuit configurations. Discuss battery-selection switches, their locations, and operation. Cover service requirements and procedures for battery-isolator systems. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 19 Describe the typical exhaust systems used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use actual equipment or illustrations to discuss the design and functioning of typical components of an outboard-engine exhaust system. Show examples of both two- and four-stroke-cycle engines. Discuss these systems in the detail required as a result of your students' instructional background. If additional resources are required, refer to MAVCC's *Power Product Equipment Technician: Engine Systems and Service*, Unit 9, "Exhaust Systems." Emphasize the differences in marine systems, such as subsurface exhaust ports, little use of mufflers, etc. Ensure that students understand the importance of exhaust-gas removal and its role in proper engine operation. Discuss service requirements for exhaust systems and symptoms of improper operation. Emphasize safety precautions related to exhaust systems and especially the operation of engines with the exhaust port above the water line. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 20 List the probable causes of engine overheating.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Review the role of the lubrication system, cooling system, and ignition timing as well as air cooling in maintaining proper engine temperature. Provide the students with examples of the problems listed. For example, show defective head gaskets and cracked heads. Display water pumps with defects and clogged ports. Use service manuals to discuss lubricant requirements and thermostat ratings. Use a troubleshooting chart such as that provided in Assignment Sheet 4, "Interpret an Outboard-Engine Troubleshooting Chart," to discuss overheating conditions and likely symptoms. Emphasize the need for clean, properly maintained engines. Describe and demonstrate related service procedures. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Suggested Activities

Objective 21 Define the typical tasks performed for engine tune-ups.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Tailor this objective to fit the practices in your area. Emphasize that there is no single definition of a tune-up. The procedures listed in the information sheet are typical. Demonstrate each procedure on a variety of engines and explain the importance of each procedure. Emphasize the proper use of tools and instruments. Many modern engines are equipped with on-board computer systems that provide service codes to assist the technician in determining service requirements. The nature and meaning of these codes vary widely among manufacturers. Discuss, demonstrate, and train these procedures to the extent appropriate to your program. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 22 State guidelines for performing engine tune-ups.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Build your discussion of the previous objective by demonstrating good practices in performing engine tune-ups, especially those that may not be stated in specific service-manual procedures. Emphasize that it does no good to adjust the carburetor settings and timing if contaminated fuel is the cause of poor engine performance. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Assignment Sheet 1 Select the correct fuel and oil for outboard-engine applications.

- Have students locate Assignment Sheet 1. Read the introduction and directions to the assignment. **(Reading/listening for direction)**

- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Listening, reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**

- Answer any student questions and have students complete Assignment Sheet 1.

Assignment Sheet 2 Determine parts and specifications for engine-support systems.

- Have students locate Assignment Sheet 2. Read the introduction and directions to the assignment. **(Reading/listening for direction)**

- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Listening, reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**

- Answer any student questions and have students complete Assignment Sheet 2.

Assignment Sheet 3 Determine outboard-engine tune-up specifications and parts requirements.

- Have students locate Assignment Sheet 3. Read the introduction and directions to the assignment. **(Reading/listening for direction)**
- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Listening, reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**
- Answer any student questions and have students complete Assignment Sheet 3.

Assignment Sheet 4 Interpret an outboard-engine troubleshooting chart.

- Have students locate Assignment Sheet 4. Read the introduction and directions to the assignment. **(Reading/listening for direction)**
- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Listening, reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**
- Answer any student questions and have students complete Assignment Sheet 4.

Job Sheet 1 Fuel, start, operate, and shut down outboard engines.

- Have students locate Job Sheet 1 and the worksheet associated with the job sheet. Demonstrate the procedures for fueling, starting, operating, and shutting down outboard engines. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an engine and have them complete the preperformance check (Part A) on the worksheet. Evaluate the preperformance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 1.

Job Sheet 2 Perform routine maintenance on fuel systems.

- Have students locate Job Sheet 2 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on fuel systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 2.

Job Sheet 3 Repair fuel systems.

- Have students locate Job Sheet 3 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing fuel systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an engine with a fuel system that requires repair and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 3.

Job Sheet 4 Perform routine maintenance on lubrication systems.

- Have students locate Job Sheet 4 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on lubrication systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 4.

Job Sheet 5 Repair lubrication systems.

- Have students locate Job Sheet 5 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing lubrication systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an engine with a lubrication system that requires repair and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 5.

Job Sheet 6 Perform routine maintenance on cooling systems.

- Have students locate Job Sheet 6 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on cooling systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

Suggested Activities

- Provide students with an engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 6.

Job Sheet 7 Repair cooling systems.

- Have students locate Job Sheet 7 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing cooling systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an engine with a cooling system that requires repair and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 7.

Job Sheet 8 Perform routine maintenance on ignition systems.

- Have students locate Job Sheet 8 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on ignition systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 8.

Job Sheet 9 Repair ignition systems.

- Have students locate Job Sheet 9 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing ignition systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an engine with a ignition system requiring repair and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 9.

Job Sheet 10 Perform routine maintenance on starting systems.

- Have students locate Job Sheet 10 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on starting systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

Suggested Activities

- Provide students with an engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 10.

Job Sheet 11 Repair starting systems.

- Have students locate Job Sheet 11 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing starting systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an engine with a starting system requiring repair and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 11.

Job Sheet 12 Perform routine maintenance on charging systems.

- Have students locate Job Sheet 12 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on charging systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 12.

Job Sheet 13 Repair charging systems.

- Have students locate Job Sheet 13 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing a charging system. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an engine with a charging system requiring repair and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 13.

Job Sheet 14 Perform minor tune-ups.

- Have students locate Job Sheet 14 and the worksheet associated with the job sheet. Demonstrate the procedures for performing minor tune-ups. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

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- Provide students with an engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 14.

Job Sheet 15 Perform major tune-ups.

- Have students locate Job Sheet 15 and the worksheet associated with the job sheet. Demonstrate the procedures for performing major tune-ups. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 15.

Job Sheet 16 Troubleshoot failure-to-start in outboard engines.

- Have students locate Job Sheet 16 and the worksheet associated with the job sheet. Demonstrate the procedures for troubleshooting failure-to-start in outboard engines. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an engine exhibiting a failure-to-start condition and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 16.

Job Sheet 17 Perform failure analysis on outboard engines.

- Have students locate Job Sheet 17 and the worksheet associated with the job sheet. Demonstrate the procedures for performing failure analysis on outboard engines. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with a failed engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 17.

Evaluation

- Evaluate the assignment sheets. See the evaluation criteria listed at the top of each assignment sheet as well as the teacher page "Answers to Assignment Sheets."

- Evaluate the job sheets.

  When the student is ready to perform a specific task, obtain a copy of the worksheet associated with each job sheet. Worksheets may be found in the student edition and in the teacher pages. Then, observe the student performing the procedure.

Suggested Activities

After the student has completed the procedure, rate the student using the criteria provided on the worksheet. If the student's performance is unacceptable, have the student review the materials and perform the procedure again for evaluation.

Two sample performance evaluation keys are provided below. Many other keys are available. Select one evaluation key (grading scale) that best fits your program needs.

Performance Evaluation Keys

Sample A

4 — Skilled—Can perform job with no additional training.
3 — Moderately skilled—Has performed job during training program; limited additional training may be required.
2 — Limited skill—Has performed job during training program; additional training is required to develop skill.
1 — Unskilled—Is familiar with process, but is unable to perform job.

Sample B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

- Give the written test. See the teacher page "Written Test."
- Evaluate the written test. See the teacher page "Answers to Written Test."
- Compile written-test, assignment-sheet, and job-sheet scores. See the teacher page "Unit Evaluation Form."
- Reteach and retest as required.

Suggested resources

Resources used in developing this unit

Print media

- Buchanan, George. *The Boat Repair Manual.* New York: Arco Publishing, Inc., 1985.
- *Everything You Need to Know About Propellers*, 4th ed. Brunswick Corporation, 1992.
- Gladstone, Bernard, and Tom Bottomley. *Boatkeeper: The Boatowner's Guide to Maintenance, Repair, and Improvement.* New York: Hearst Marine Books, 1984.

Suggested Activities

- Kendall, Dave. *The Complete Book of Boat Maintenance and Repair.* Garden City, New York: Doubleday and Company, Inc., 1975.
- Mercury Marine. Service manuals used in the development of this unit include:
  - Accessories Parts Catalog, 1998.
  - Service Manual, Models 135, 150, 175, 200, 225, September 1997.
  - Service Manual, Models 9.9/15, 9.9/15 Bigfoot (4-Stroke), August 1998.
  - Service Manual, Models 40, 50, 55, 60, January 1998.
  - Service Manual, Models 4, 5 (4-Stroke), January 1999.
  - Service Manual, Models V-300, V-3.4 Litre, 1984.
  - Service Manual, Remote Controls, September 1998.
  - Service Manual, Power Steering, 1996.
- Outboard Marine Corporation (OMC). Service manuals used in the development of this unit include:
  - 1999 EE 60° LV Service Manual
  - 1999 EE 90° LV Service Manual
  - 1999 EE 40 thru 70 Service Manual
  - 1999 EE 25, 35 Service Manual 3-Cylinder
  - 1999 EE 9.9 thru 30 Service Manual
  - 1999 EE 2 thru 8 Service Manual
  - 1999 EE 60° V4, V6 FFI Service Manual
  - 1999 EE 90° V6 FFI Service Manual
  - 1999 EE 70 4-Stroke Service Manual
  - 1999 EE 5 thru 15 4-Stroke Service Manual
  - 1999 EE Accessories Service Manual
- *Outboard Repair.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1985.
- *Parts Catalog: Model TOB-300.* Tanaka, 1998.
- Sherman, Edwin R. *Outboard Engines: Maintenance, Troubleshooting, and Repair.* Camden, Maine: International Marine, a division of The McGraw-Hill Companies, 1997.
- United States Coast Guard. *Skipper's Safe Boating Course*, 2nd ed. St. Louis, Missouri: Mosby-Year Book, Inc., 1996.

Suggested supplemental resources

Print media

- *Boating Magazine.* 1633 Broadway, New York, New York 10019, (212) 767-5585.
- *Motor Boating and Sailing* magazine. 250 W. 55th St., New York, New York 10019, (212) 649-4099.
- *Trailer Boats.* Poole Publications, Inc., 20700 Belshaw Ave., Carson, California 90746-3510, (310) 537-6322.

Suggested Activities

- Service manuals and operator's manuals for systems and equipment covered in this unit. Available from equipment manufacturers.
- Parts catalogs for systems covered in this unit. Available from equipment manufacturers.

Nonprint media

- Small-engine video series. Each of these 15-minute VHS programs covers the title topics and carry 1993 and 1994 copyrights. The first program includes information about outboard engines, as well as other types of power product equipment. The remaining programs use Briggs and Stratton 3- and 5-hp engines as examples, but of course, many of the principles apply to outboard engines. The videotapes are available from Shopware, P.O. Box 2708, Charleston, West Virginia 25330, (800) 487-3392. Available titles include:
  - The Basics
  - Four-Stroke-Engine Operation
  - Engine Disassembly
  - Engine Reassembly
  - Completing the Reassembly
  - Fuel-System Diagnosis
  - Ignition-System Diagnosis
  - Systems Diagnosis
  - Maintenance and Storage
  - Two-Stroke-Engine Operation
  - Two-Stroke-Engine Disassembly
  - Two-Stroke-Engine Assembly
  - Two-Cycle-Engine Troubleshooting
  - Servicing and Storing Two-Cycle Engines
- *Outboard Motors.* This VHS program discusses safety in outboard-engine operation as well as maintenance for the power head and lower unit. Available from Shopware.
- *Multimedia Small Engines.* These 1998 CD-ROM programs come in three parts that combine video, animation, text, and photos to discuss operation and service of small engines for computers running Windows. The first program covers engine design and the ignition system. The second program discusses lubrication, cooling, speed control, and fuel systems. The final program focuses on fault diagnosis and overhaul. Available from Shopware.

Organizations

- National Marine Manufacturers Association. A good source of information about trends in watercraft sales and production. 200 E. Randolph Drive, Suite 5100, Chicago, Illinois 60601, (312) 946-6200, website http://www.nmma.com.

Suggested Activities

- Association of Marine Technicians (AMTECH). An organization dedicated to improving marine service through cooperation, certification, and education. 455 Knollwood Terrace, Roswell, Georgia 30075-3416, (800) 467-0982.

Operation and Service of Engine-Support Systems
Unit 2

Answers to Assignment Sheets

Assignment Sheet 1—The correct answers will vary depending on the specific engine referenced, and may vary depending on model year, serial number, emissions equipment, engine configuration, intended application, and other factors. Instructors should accept answers based on the reference materials available to the students.

Assignment Sheet 2—The correct answers will vary depending on the specific engine referenced, and may vary depending on model year, serial number, emissions equipment, engine configuration, intended application, and other factors. Instructors should accept answers based on the reference materials available to the students.

Assignment Sheet 3—The correct answers will vary depending on the specific engine referenced, and may vary depending on model year, serial number, emissions equipment, engine configuration, intended application, and other factors. Instructors should accept answers based on the reference materials available to the students.

Assignment Sheet 4

1. d
2. c
3. c
4. b
5. c

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Operation and Service of Engine-Support Systems
Unit 2

Answers to Written Test

1. System that supports and sustains the operation of the engine

2. Answers may appear in any order.

   - Fuel system
   - Lubrication system
   - Cooling system
   - Ignition system
   - Starting system
   - Charging system
   - Exhaust system

3. a. combustion chamber
   b. carburetors; fuel-injection
   c. diaphragm; gravity
   d. fuel injectors; injectors; electronic-control; injectors
   e. power-head; separate

4. a. 4
   b. 2
   c. 3
   d. 5
   e. 1

5. a. The tank must be able to withstand the marine environment

   b. The tank or lines must prevent sediments from reaching the engine

   c. Fuel tanks must be vented to allow air to enter the tank as the fuel level goes down

   d. Large fuel tanks often include baffles to prevent excessive sloshing of the fuel

   e. The tank must be securely installed to prevent the tank from coming loose as the boat travels

   f. Many tanks will include primer bulbs to allow the manual pumping of fuel to the engine for cold starts

6. Answer should include any seven of the following.

   - Empty fuel tank
   - Closed or clogged fuel-tank air vent
   - Contaminated fuel
   - Incorrect fuel/oil mixture

Answers to Written Test

- Leaky or weak fuel pump
- Clogged fuel line, screens, or filter
- Incorrect float setting
- Incorrect needle-valve settings or dirty needle valves
- Binding of mechanical parts

7. a. Oil; oil
   b. Two-stroke-cycle
   c. two-stroke-cycle
   d. Four-stroke-cycle
   e. four-stroke-cycle

8. a. intake; filter; pump; thermostat; water jacket; exhaust
   b. thermostat; pump

9. a. Has longer impeller vanes so that it moves a larger volume of water through the pump

   b. Has smaller impeller vanes so that it moves a smaller volume of water through the pump; however, it applies more pressure

10. a. drive shaft
    b. Water
    c. drive shaft; volume
    d. outlet; outlet; inlet

11. a. drive shaft
    b. Water
    c. drive shaft; volume
    d. outlet; outlet; inlet
    e. inlet; outlet

12. a. flywheel
    b. magnets
    c. generating
    d. magnets; generating
    e. polarity; magnets
    f. rectifier
    g. capacitor
    h. spark plug
    i. trigger pulse
    j. trigger pulse
    k. capacitor
    l. capacitor; primary
    m. primary; secondary
    n. secondary; lead wire; fuel
    o. combustion cycle

Answers to Written Test

13. a. 5
    b. 3
    c. 4
    d. 1
    e. 2

14. a. 2
    b. 4
    c. 7
    d. 8
    e. 1
    f. 3
    g. 6
    h. 9
    i. 5

15. Answer should include any twelve of the following.

- Incorrect timing
- Broken or damaged spark plug
- Fouled spark plug
- Improperly gapped spark plug
- Incorrect spark plug
- Ignition points not properly gapped
- Ignition points burned or dirty
- Weak or damaged coil
- Weak condenser
- Cracked distributor cap or rotor
- Faulty electronic ignition component
- Loose or broken ignition wires
- Loose or worn magneto plates (stator plates)
- Worn cam or cam follower
- Poor grounding

16. a. rope-rewind; motor
    b. batteries; nonconductive; conductive; water
    c. sealed

17. a. battery; battery-powered
    b. flywheel
    c. alternator

18. To allow the charging system to charge both the starting battery and an auxiliary battery at the same time while preventing accessories that are connected to the auxiliary battery from drawing current from the starting battery.

19. Except for the exhaust valve or port, most outboard-engine exhaust systems do not contain moving parts.

Generally, there is a tube that connects the exhaust port of the combustion chamber through the midsecton to an exit port below the water level.

Mufflers and similar devices are not usually required.

Answers to Written Test

20. Answer should include any six of the following.

- Inadequate lubricant
- Clogged water intake
- Faulty water pump
- Defective thermostat
- Incorrect thermostat
- Clogged or corroded water passages
- Improper ignition timing
- Leaking head gasket or cracked head

21. a. Clean or replace air box to provide a clean air supply to the carburetor

    b. Adjust the carburetor float level, clean fuel orifices and jets, replace the fuel filter, test the fuel pump or injectors to ensure delivery of a correct quantity of clean fuel for the compression-ignition stroke

    c. Change the oil and filter to provide adequate lubrication and to ensure proper sealing of the piston rings

    d. Adjust the armature air gap, adjust the breaker gaps, clean and regap or replace the spark plugs, and set the ignition timing to provide sufficient spark at the correct time during the internal-combustion process

    e. Remove dirt and grime from the engine to ensure that moving parts are not obstructed and to allow proper cooling; ensure that parts move without binding, that fasteners are properly tightened, and that gaskets do not leak

22. Answer should include any five of the following.

- Ensure that the battery is fully charged.

- Ensure that the spark plug is clean, properly gapped, and fully seated, and that it is the correct spark plug for the engine.

- Ensure that the fuel is fresh.

- Ensure that there is adequate lubrication.

- Ensure that all filters are in place, properly installed, and clean.

- Ensure that the engine is clean and can obtain adequate air.

- Perform preliminary checks of the ignition timing and fuel systems.

Operation and Service of Engine-Support Systems
Unit 2

Written Test

Name ______________________________ Score ______________

1. Define the term *engine-support system*. Write your answer on the blank lines provided beside the term below.

   Engine-support system ______________________________

   ____

2. List the major engine-support systems used in outboard engines. Write your answers on the blank lines provided below.

   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________
   e. ______________________________
   f. ______________________________
   g. ______________________________

3. Complete statements that describe the typical fuel systems used in outboard engines. Write your answers on the blanks provided in the statements below and on the next page.

   a. The fuel system consists of a device for storing the fuel, the fuel lines, fuel filters, a fuel pump, and a means of metering and delivering the fuel to the ______________.

   b. Most outboard engines use ____________ that are essentially the same as those used in other types of power product equipment. However, some larger engines use computer-controlled ______________ systems.

   c. The majority of carbureted systems use ____________ fuel pumps, though some smaller engines have fuel tanks mounted on the engine with ____________ fuel flow.

d. Most ________________ are not internally serviceable and must be replaced if not operating properly. Fuel-delivery problems may result from dirty ________________ or from problems in the ________________ unit while the ________________ themselves are performing properly.

e. Another portion of the fuel system that is likely to differ in outboard engines as opposed to land-based equipment is the fuel tank. While some small outboard engines have the fuel tank integrated into the ________________ housing, many have a ________________ fuel tank that carries a relatively large quantity of fuel and is designed to survive the marine environment and movement of the boat while delivering a steady supply of uncontaminated fuel.

4. Match types of fuels used in outboard engines to their correct applications. Write the numbers on the blanks.

_______ a. Used only in diesel engines
_______ b. Used in gasoline engines designed after the late 1970s
_______ c. Used to decrease the production of carbon monoxide in outboard-engine exhaust; are not recommended for use in most outboard engines
_______ d. Used primarily as a fuel additive; only rarely used as a fuel
_______ e. Used in gasoline engines designed before the late 1970s

1. Leaded gasoline
2. Unleaded gasoline
3. Blended fuels
4. Diesel fuel
5. Alcohol

5. Describe the factors considered in the design of outboard-engine fuel tanks. Write your answers on the blank lines provided beside each of the terms below and on the next page.

a. Corrosion resistance ____

____

____

b. Filter system ____

____

____

c. Venting ____

____

____

d. Baffle systems ____

____

____

e. Secure installation ____

____

____

f. Primer system ____

____

____

6. List seven of the probable causes of fuel-system problems. Write your answers on the blank lines provided below.

a. ____
b. ____
c. ____
d. ____
e. ____
f. ____
g. ____

7. Complete statements that describe the typical lubrication systems used in outboard engines. Write your answers on the blanks provided in the statements below and on the next page.

a. The lubrication system consists of a supply of ____________ and a means of circulating the ____________ around the moving parts of the engine.

b. ________________ systems generally use oil mixed with the fuel. As the mixture is drawn into the crankcase, it lubricates the crankshaft and bearings. The cylinder walls in the combustion chamber are lubricated by the oil in the fuel that enters the combustion chamber.

c. In ____________________ engines two principal ways are used to combine oil with the fuel. One way is to manually mix oil with the gasoline before filling the fuel tank, and another way is to use an oil-injection system that sprays oil into the fuel, often as the fuel enters the crankcase.

d. ____________________ engines generally flow oil over moving parts without mixing it with fuel; they are likely to use a pressurized oil system similar to those used on some multicylinder motorcycle, snowmobile, or garden-tractor engines.

e. Lubrication systems in ____________________ engines include an oil reservoir, a pump that is usually driven by the crankshaft, oil channels to carry the oil to moving parts, and channels to return oil to the reservoir. Pressurized lubrication systems are also likely to have oil filters.

8. Complete statements that describe the typical cooling systems used in outboard engines. Write your answers on the blanks provided in the statements below.

a. Typically, an outboard-engine cooling system will consist of an ________________ port below the normal water level, a ________________ to prevent debris from entering the cooling system, a ________________ to move the water through the cooling system, a ________________ to stop the flow of water when the engine is cold or adequately cooled, channels—called a ____________________—through which water circulates in contact with the heated components of the power head, and an ________________ port that removes heated water from the engine.

b. Cooling-system designs may vary in details such as the location of the ________________, the type of ________________ used, and other features, but they all operate in the same general way.

9. Describe the types of water pumps commonly used in outboard-engine cooling systems. Write your answers on the blank lines provided beside the terms below and on the next page.

a. Volume-type water pump ____

____

____

b. Pressure-type water pump ____

____

____

10. Complete statements about the principles of operation of volume-type water pumps. Write your answers on the blanks provided in the statements below.

    a. The ______________ passes through the pump body at an offset from the center of the pump so that one portion of the pump is larger than the other portion.

    b. ______________ enters into the large portion of the pump.

    c. The ______________ rotates the impeller so that water is moved around the pump from the large portion to the small portion; because of the decreased ______________ in the small portion, the pressure on the water increases.

    d. Water flows through the ______________ port and undergoes a further increase in pressure and speed because the ______________ port is smaller in diameter than the ______________ port.

11. Complete statements about the principles of operation of pressure-type water pumps. Write your answers on the blanks provided in the statements below.

    a. The ______________ passes through the pump body at an offset from the center of the pump so that one portion of the pump is larger than the other portion.

    b. ______________ enters into the large portion of the pump.

    c. The ______________ rotates the impeller so that water is moved around the pump from the large portion to the small portion; because of the decreased ______________ in the small portion, the pressure on the water increases.

    d. Water flows through the ______________ port and undergoes a further increase in pressure and speed because the ______________ port is smaller in diameter than the ______________ port.

    e. Because of the small pump-body volume, the movement of the water from the ______________ to the ______________ port happens very quickly and, though the volume of water moved is small, the change in pressure occurs rapidly.

Written Test

12. Complete statements about the principles of operation of outboard-engine ignition systems. Write your answers on the blanks provided in the statements below.

a. The ____________________ is mounted to the end of the crankshaft and rotates with it.

b. ____________________ are mounted on the flywheel.

c. A ____________________ coil is mounted next to the path of the rotating flywheel.

d. As the ____________________ on the flywheel move past the ____________________ coil, electrical flow is induced in the windings of the coil.

e. The induced electricity alternates flow direction as the ____________________ of the rotating ____________________ switch between north and south poles.

f. The electrical flow is directed through a ____________________ circuit, where it is converted to direct current.

g. The converted electrical current flows to a ____________________, where it is stored.

h. The ignition system monitors engine conditions to determine the appropriate time to send current to the ____________________________.

i. A ____________________________ is generated at the appropriate time.

j. The ____________________________ causes a switch to close.

k. The closed switch allows the ____________________ to discharge.

l. The ____________________ current flows to the ____________________ winding of the ignition coil.

m. As electricity flows through the ____________________ winding of the ignition coil, current is induced in the ____________________ winding of the ignition coil.

n. The voltage in the ____________________ winding increases enough to overcome the resistance of the spark gap, it flows through the spark-plug ____________________, arcs across the gap, igniting the ____________________ mixture, and flows to ground.

o. The process repeats itself with each rotation of the flywheel, generally resulting in one complete ____________________________ for each cylinder with each revolution.

Written Test

13. Match types of tests performed on outboard-engine ignition systems to their correct purposes. Write the numbers on the blanks.

_______ a. Checks diagnostic codes stored in the engine's computer memory

_______ b. Checks the value of a signal being produced by a sensor or other system component

_______ c. Verifies that current flows between the electrodes of the spark plug

_______ d. Verifies electrical flow from one point in a circuit to another, including from one connector to another in a component

_______ e. Checks the ease with which current flows between two points in a circuit

1. Continuity test
2. Resistance test
3. Output test
4. Spark-plug-gap test
5. Service-code retrieval

14. Match tools and instruments used to test ignition systems to their correct purposes. Write the numbers on the blanks.

_______ a. Measures electrical current in a circuit and is used to perform continuity tests

_______ b. Measures voltage and is used to perform output tests

_______ c. Verifies spark across a spark plug

_______ d. Perform specific tests or allow engine systems to be connected to other test equipment

_______ e. Indicates whether or not current is present at a point in a circuit

_______ f. Measures resistance and is used to perform resistance tests

_______ g. Measures current, resistance, and voltage and is generally suitable for a variety of tests

_______ h. Reads and erases codes stored in the memory of the engine computer

_______ i. Measures voltage and indicates the highest level of voltage present in an alternating current

1. Continuity light
2. Ammeter
3. Ohmmeter
4. Voltmeter
5. Peak-reading voltmeter
6. Multimeter
7. Spark-plug-gap tester
8. Special equipment
9. Service-code retrieval system

15. List twelve of the probable causes of ignition-system problems. Write your answers on the blank lines provided below and on the next page.

a. ____

b. ____

c. ____

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

i. ______________________________

j. ______________________________

k. ______________________________

l. ______________________________

16. Complete statements that describe the typical starting systems used in outboard engines. Write your answers on the blanks provided in the statements below.

  a. Outboard engines generally use one of two methods to begin the internal-combustion process by turning the flywheel. The flywheel can be turned manually using any of the ____________________ systems or electrically by a ____________________ powered from a battery.

  b. The most likely difference between an electrical starting system on an outboard engine and that used on land-based equipment is that special precautions are used to protect marine ____________________ from their environment and to provide grounding to them. In most land-based equipment, the starting system and other battery-powered equipment are grounded through the equipment chassis to complete the ground circuit to the battery. This approach is not possible on boats because the chassis or hull is made of a ____________________ material such as wood or fiberglass or of a ____________________ material such as aluminum that would just as easily conduct the current into the ____________________.

  c. Outboard-engine starters must be ____________________ to prevent sparks from igniting fuel vapors.

Written Test

17. Complete statements that describe the typical charging systems used in outboard engines. Write your answers on the blanks provided in the statements below.

    a. The purpose of the charging system is to maintain an adequate level of charge in the ______________________ so that the boat can be started and other ______________________ systems operated.

    b. As with other types of power product equipment, charging is generally accomplished through the use of electricity generated by the rotation of the ________________.

    c. Some outboard engines have a separate belt- or shaft-driven ________________.

18. State the purpose of battery isolators. Write your answer on the blank lines provided below.

    ____

    ____

    ____

    ____

    ____

19. Describe the typical exhaust systems used in outboard engines. Write your answer on the blank lines provided below.

    ____

    ____

    ____

    ____

    ____

    ____

    ____

    ____

    ____

20. List six of the probable causes of engine overheating. Write your answers on the blank lines provided below.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

    e. ______________________________

    f. ______________________________

21. Define the typical tasks performed for engine tune-ups. Write your answers on the blank lines provided beside the terms below and on the next page.

    a. Service air box ______________________________

    ____

    ____

    ____

    ____

    b. Service fuel system ______________________________

    ____

    ____

    ____

    ____

    c. Service lubrication system ______________________________

    ____

    ____

    ____

    ____

d. Service ignition system ______________________________

____

____

____

____

e. Clean engine and ensure proper assembly ______________________________

____

____

____

____

22. State five guidelines for performing engine tune-ups. Write your answers on the blank lines provided below.

a. ______________________________
b. ______________________________
c. ______________________________
d. ______________________________
e. ______________________________

Permission to duplicate this test is granted.

Operation and Service of Engine-Support Systems
Unit 2

Unit Evaluation Form

Student name ______________________________ Unit rating ______________

Assignment-sheet ratings

Assignment Sheet 1—Select the Correct Fuel and Oil for Outboard-Engine Applications Rating ________

Comments: ____

____

Assignment Sheet 2—Determine Parts and Specifications for Engine-Support Systems Rating ________

Comments: ____

____

Assignment Sheet 3—Determine Outboard-Engine Tune-Up Specifications and Parts Requirements Rating ________

Comments: ____

____

Assignment Sheet 4—Interpret an Outboard-Engine Troubleshooting Chart Rating ________

Comments: ____

____

Job-sheet ratings

Job Sheet 1—Fuel, Start, Operate, and Shut Down Outboard Engines Rating ________

Comments: ____

____

Job Sheet 2—Perform Routine Maintenance on Fuel Systems Rating ________

Comments: ____

____

Unit Evaluation Form

Job Sheet 3—Repair Fuel Systems Rating ________

Comments: ______________________________

____

Job Sheet 4—Perform Routine Maintenance on Lubrication Systems Rating ________

Comments: ______________________________

____

Job Sheet 5—Repair Lubrication Systems Rating ________

Comments: ______________________________

____

Job Sheet 6—Perform Routine Maintenance on Cooling Systems Rating ________

Comments: ______________________________

____

Job Sheet 7—Repair Cooling Systems Rating ________

Comments: ______________________________

____

Job Sheet 8—Perform Routine Maintenance on Ignition Systems Rating ________

Comments: ______________________________

____

Job Sheet 9—Repair Ignition Systems Rating ________

Comments: ______________________________

____

Job Sheet 10—Perform Routine Maintenance on Starting Systems Rating ________

Comments: ______________________________

____

Job Sheet 11—Repair Starting Systems Rating ________

Comments: ______________________________

____

Unit Evaluation Form

Job Sheet 12—Perform Routine Maintenance on Charging Systems Rating ________

Comments: ____

____

Job Sheet 13—Repair Charging Systems Rating ________

Comments: ____

____

Job Sheet 14—Perform Minor Tune-Ups Rating ________

Comments: ____

____

Job Sheet 15—Perform Major Tune-Ups Rating ________

Comments: ____

____

Job Sheet 16—Troubleshoot Failure-to-Start in Outboard Engines Rating ________

Comments: ____

____

Job Sheet 17—Perform Failure Analysis on Outboard Engines Rating ________

Comments: ____

____

Written-test scores

Pretest ________ Posttest ________ Other ________

Comments: ____

____

Teacher signature ______________________ Date ____________

Student signature ______________________ Date ____________

Permission to duplicate this form is granted.

Job Sheet 1

Worksheet—Fuel, Start, Operate, and Shut Down Outboard Engines

Name ______________________ Attempt number ________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment model/type and code ______________________

  ____

- List references used regarding fueling, starting, operating, and shutting down the engine.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- Describe type of fuel to be used and list additives or oil mixture and ratio.

- Describe starting procedure.

- Describe shut-down procedure.

Instructor's signature ______________________

Job Sheet 1

Worksheet—Fuel, Start, Operate, and Shut Down Outboard Engines

---

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Controls used correctly.	______
Safety precautions observed.	______
Operation within specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 2

Worksheet—Perform Routine Maintenance on Fuel Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: **Pre-performance check**

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Worksheet—Perform Routine Maintenance on Fuel Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 3

Worksheet—Repair Fuel Systems

Name ________________________ Attempt number __________

Date ________________________

Part A: Pre-performance check

Job ________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ________________________

  Equipment model/type and code ________________________

  ____

- Complete the following service-manual information.

  Service-manual title ________________________

  Section/page number of procedure ________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ________________________

Job Sheet 3

Worksheet—Repair Fuel Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	_______
Procedures completed correctly.	_______
Proper tools used correctly.	_______
Safety precautions observed.	_______
Service meets specifications.	_______
Clean-up and follow-up actions adequate.	_______
Overall rating	_______

Evaluator's comments ____

____

____

Job Sheet 4

Worksheet—Perform Routine Maintenance on Lubrication Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 4

Worksheet—Perform Routine Maintenance on Lubrication Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 5

Worksheet—Repair Lubrication Systems

Name ______________________ Attempt number ________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 5

Worksheet—Repair Lubrication Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	________
Procedures completed correctly.	________
Proper tools used correctly.	________
Safety precautions observed.	________
Service meets specifications.	________
Clean-up and follow-up actions adequate.	________
Overall rating	________

Evaluator's comments ____

____

____

Job Sheet 6

Worksheet—Perform Routine Maintenance on Cooling Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: **Pre-performance check**

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

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Instructor's signature ______________________

Job Sheet 6

Worksheet—Perform Routine Maintenance on Cooling Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	________
Procedures completed correctly.	________
Proper tools used correctly.	________
Safety precautions observed.	________
Service meets specifications.	________
Clean-up and follow-up actions adequate.	________
Overall rating	________

Evaluator's comments ____

____

____

Job Sheet 7

Worksheet—Repair Cooling Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Worksheet—Repair Cooling Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 8

Worksheet—Perform Routine Maintenance on Ignition Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: **Pre-performance check**

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Worksheet—Perform Routine Maintenance on Ignition Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 9

Worksheet—Repair Ignition Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 9

Worksheet—Repair Ignition Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 10

Worksheet—Perform Routine Maintenance on Starting Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 10

Worksheet—Perform Routine Maintenance on Starting Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 11

Worksheet—Repair Starting Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 11

Worksheet—Repair Starting Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 12

Worksheet—Perform Routine Maintenance on Charging Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 12

Worksheet—Perform Routine Maintenance on Charging Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 13

Worksheet—Repair Charging Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: **Pre-performance check**

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 13

Worksheet—Repair Charging Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 14

Worksheet—Perform Minor Tune-Ups

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Worksheet—Perform Minor Tune-Ups

Part B: Performance evaluation

Evaluation criteria	Rating
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 15

Worksheet—Perform Major Tune-Ups

Name ______________________ Attempt number ________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 15

Worksheet—Perform Major Tune-Ups

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	_______
Procedures completed correctly.	_______
Proper tools used correctly.	_______
Safety precautions observed.	_______
Service meets specifications.	_______
Clean-up and follow-up actions adequate.	_______
Overall rating	_______

Evaluator's comments ____

____

____

Job Sheet 16

Worksheet—Troubleshoot Failure-to-Start in Outboard Engines

Name Attempt number

Date

Part A: Pre-performance check

Job

- Complete the following information concerning the assigned equipment.

  Equipment brand

  Equipment model/type and code

- Complete the following service-manual information.

  Service-manual title

  Section/page number of procedure

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature

Job Sheet 16

Worksheet—Troubleshoot Failure-to-Start in Outboard Engines

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 17

Worksheet—Perform Failure Analysis on Outboard Engines

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Worksheet—Perform Failure Analysis on Outboard Engines

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Power-Output Systems
Unit 3

Suggested Activities

Instructional plan

Preparation

- Review the unit in the student edition and plan your presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review the unit introduction and teaching suggestions included in the delivery and application section below, and plan classroom activities. Also note suggestions for media and supplemental materials.

  Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.

- Prepare the classroom by displaying posters, equipment, and tools related to power-output systems.
- Make transparencies from the transparency masters included in the teacher pages of this unit.
- Select teacher components (written test, unit evaluation form) you want to distribute to your students. Copy and prepare these components for distribution.
- Review the job sheets and worksheets in the student edition and locate the worksheet masters included in the teacher pages of this unit. Copy and prepare extra worksheets for distribution to your students.

Delivery and application

Unit introduction

The skill areas appearing in bold-face type in the unit introduction and teaching suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want.* These have been adapted by MAVCC.

- Provide students with copies of the student materials. You may choose to begin by discussing the objective sheet. Review the unit and specific objectives with the students. Discuss how meeting the unit objective will improve their employability or will increase their value as an employee. Explain how the specific objectives support the unit objective. **(Listening; adapting to the organization's traditional modes of operation; emphasizing personal and career development)**
- Introduce the unit by having the students discuss what makes an outboard-engine boat move through the water. Guide the discussion so that students realize that the mechanical output of the engine is transferred from the engine, along a drive shaft, and through a gearcase to turn a propeller. Discuss how a propeller works like the engine's water pump studied in the previous unit. The propeller

displaces water, which creates a low-pressure area into which more water flows, causing the boat to move ahead. Relate this process to drive trains on other types of power product equipment and state that the work done by the outboard engine is providing the boat with controlled movement through the water. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Teaching suggestions

Objective 1 Describe the typical power-output systems used in outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Expand on your discussion in the introduction to describe typical power-output systems. Use Transparency 1, "Major Components of Power-Output Systems," and Figure 1 in the information sheet to illustrate your discussion. Point out that the components of this system are generally housed in the midsection and lower unit. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 2 Match the major components of power-output systems to their correct functions.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use Transparency 1, Figure 1 in the information sheet, other illustrations, actual equipment, and models to present information about the common components of the midsection and lower unit. Discuss the function of each component and its role in the production and output of controlled, directed power to propel the boat. Display a variety of designs for the various components, such as different types of brackets, various water-inlet and exhaust-port designs, shifting and non-shifting gearcases, different types of propellers, etc. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 3 List the design features used to classify power-output systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Display various shifting and non-shifting power-output systems. Relate them to engine manufacturers and engine designs. Show exposed gear trains to demonstrate the shifting capabilities of each, including positioning for forward, reverse, and neutral configurations. Provide examples of tiller and remote shifting controls. If electrical shift systems are in use in your region, discuss their design, operation, and service. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Suggested Activities

Objective 4 Complete statements about the principles of operation of mechanical-shifting power-output systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Continue the discussion begun in Objective 3 by going into detail about the operation of mechanical shifting systems. Point out that some older boats may be equipped with electrical shifting systems that perform the same function through the use of solenoids. Discuss gear ratios and their applications in terms of engines and propellers. Discuss clutch designs and operation. Provide examples of various types of protective mechanisms for connecting the propeller and shaft. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 5 Match the major components of outboard-engine propeller assemblies to their correct functions.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use Transparency 2, "Major Components of Propeller Assemblies," the artwork in Figure 2 in the information sheet, models, actual equipment, and illustrations to show various types of propeller assemblies. Discuss the components of each and the role of each component. Use as many different designs as possible. Lead the students in a discussion of the impact of design variations on power output and how those variations may or may not be appropriate for specific boat applications. Discuss reasons for protecting the propeller for damage through the use of shear pins, special hubs, and other methods. Describe the importance of intact seals and properly maintained bearings. Provide the students with examples of damaged and failed propeller assemblies and gearcase components. Discuss the source of the damage, the effects on boat performance, and related service procedures. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 6 List the materials used in the manufacture of outboard-engine propellers.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Display propellers of various materials. Discuss the advantages and disadvantages of each for specific applications. Use Student Supplement 1, "Principles of Propeller Operation," to expand your discussion as appropriate for your course objectives. Relate these concepts to those presented in the first six objectives in terms of the components of the midsection and lower unit, component functions, etc. For example, the supplement should provide better understanding of the function of the antiventilation plate. Relate all of the information presented for specific boat applications, emphasizing those applications and propeller designs common to your area. Discuss propeller-selection considerations. Discuss service and safety considerations. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 7 Describe the principles of propeller rotation and counter-rotation.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Help the students understand the effects of the torque produced by propeller rotation. Point out that normal rotation in North America is clockwise, causing boats in this area to pull slightly to the left. Discuss the use of a second counter-rotating propeller and other methods of compensating for engine torque. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 8 List the design features used to classify propeller hubs.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Display various types of hubs, including those made of various materials and both dynamic and fixed designs. Discuss the advantages and disadvantages of each type of hub for specific boat applications. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 9 Define types of propeller defects.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Display propellers that exhibit the various types of defects included in the information sheet. Discuss causes of each type of defect and methods for avoiding these conditions. Have the students use catalogs to price propellers in order to gain an understanding of the costs involved in replacing a propeller. Discuss the effects of each type of defect on boat performance. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 10 Complete guidelines for sending a propeller to a repair facility.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Discuss the limitations of the average service facility in terms of repairing defective propellers. Specifically cover the capabilities of your own facilities and the extent of training to be provided to the students in this area. Explain your specific procedures for returning propellers for repair. Discuss the reasons for the listed guidelines and modify them as necessary to fit your program or practices common in your area or as required by repair facilities that you use. **(Listening; interpreting and processing information)**

Suggested Activities

Objective 11 State safety rules for servicing power-output systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Demonstrate safety practices listed and those required by your facility for power-output-system service, including the setup of test stands, ventilation systems, torquing requirements, etc. Explain the reason for each rule. Add those required by your facility. Use Student Supplement 2, "Hardware Used on Power-Output Systems," to discuss types of hardware associated with the power-output system. Explain uses of each and related safety rules, such as hardware that should or should not be reused, torque values, proper installation, etc. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 12 List the probable causes of poor boat performance related to power-output systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Discuss each of the causes listed and supplement the list as appropriate to your program. Provide actual examples where helpful, such as an out-of-balance propeller or incorrect trim-tab setting. Discuss probable effects of each condition and related service. Help the students to understand that they can learn a lot about possible system problems from the way customers describe boat performance, which is one reason for understanding this correlation between defects and boat performance. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Objective 13 List methods used to compensate for walking.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Discuss walking, supporting your discussion with toy boats or illustrations to help increase student comprehension. Describe how each method discussed in the information sheet would offset walking. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Assignment Sheet 1 Determine parts and specifications for power-output systems.

- Have students locate Assignment Sheet 1. Read the introduction and directions to the assignment. **(Reading/listening for direction)**
- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**

Suggested Activities

- Answer any student questions and have students complete Assignment Sheet 1.

Assignment Sheet 2 Interpret a power-output-system troubleshooting chart.

- Have students locate Assignment Sheet 2. Read the introduction and directions to the assignment. **(Reading/listening for direction)**
- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**
- Answer any student questions and have students complete Assignment Sheet 2.

Assignment Sheet 3 Calculate gear ratios.

- Have students locate Assignment Sheet 3. Read the introduction and directions to the assignment. **(Reading/listening for direction)**
- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**
- Answer any student questions and have students complete Assignment Sheet 3.

Assignment Sheet 4 Determine correct propeller characteristics for specific applications.

- Have students locate Assignment Sheet 4. Read the introduction and directions to the assignment. **(Reading/listening for direction)**
- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**
- Answer any student questions and have students complete Assignment Sheet 4.

Job Sheet 1 Perform routine maintenance on power-output systems.

- Have students locate Job Sheet 1 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on power-output systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

Suggested Activities

- Provide students with an outboard engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 1.

Job Sheet 2 Repair power-output systems.

- Have students locate Job Sheet 2 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing power-output systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an outboard engine that requires repair of the power-output system and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 2.

Job Sheet 3 Remove and replace propellers.

- Have students locate Job Sheet 3 and the worksheet associated with the job sheet. Demonstrate the procedures for removing and replacing propellers. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an outboard engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 3.

Job Sheet 4 Check rpm on propellers.

- Have students locate Job Sheet 4 and the worksheet associated with the job sheet. Demonstrate the procedures for checking rpm on propellers. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an outboard engine and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 4.

Job Sheet 5 Perform failure analysis on power-output-system components.

- Have students locate Job Sheet 5 and the worksheet associated with the job sheet. Demonstrate the procedures for performing failure analysis on power-output-system components. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

Suggested Activities

- Provide students with an outboard engine with a failed power-output system and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 5.

Evaluation

- Evaluate the assignment sheets. See the evaluation criteria listed at the top of each assignment sheet as well as the teacher page "Answers to Assignment Sheets."

- Evaluate the job sheets.

  When the student is ready to perform a specific task, obtain a copy of the worksheet associated with each job sheet. Worksheets may be found in the student edition and in the teacher pages. Then, observe the student performing the procedure.

  After the student has completed the procedure, rate the student using the criteria provided on the worksheet. If the student's performance is unacceptable, have the student review the materials and perform the procedure again for evaluation.

  Two sample performance evaluation keys are provided below. Many other keys are available. Select one evaluation key (grading scale) that best fits your program needs.

Performance Evaluation Keys

Sample A

4 — Skilled—Can perform job with no additional training.
3 — Moderately skilled—Has performed job during training program; limited additional training may be required.
2 — Limited skill—Has performed job during training program; additional training is required to develop skill.
1 — Unskilled—Is familiar with process, but is unable to perform job.

Sample B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

- Give the written test. See the teacher page "Written Test."

- Evaluate the written test. See the teacher page "Answers to Written Test."

- Compile written-test, assignment-sheet, and job-sheet scores. See the teacher page "Unit Evaluation Form."

- Reteach and retest as required.

Suggested Activities

Suggested resources

Resources used in developing this unit

Print media

- Buchanan, George. *The Boat Repair Manual.* New York: Arco Publishing, Inc., 1985.
- *Everything You Need to Know About Propellers,* 4th ed. Brunswick Corporation, 1992.
- Gladstone, Bernard, and Tom Bottomley. *Boatkeeper: The Boatowner's Guide to Maintenance, Repair, and Improvement.* New York: Hearst Marine Books, 1984.
- Kendall, Dave. *The Complete Book of Boat Maintenance and Repair.* Garden City, New York: Doubleday and Company, Inc., 1975.
- Mercury Marine. Service manuals used in the development of this unit include:
  - Accessories Parts Catalog, 1998.
  - Service Manual, Models 135, 150, 175, 200, 225, September 1997.
  - Service Manual, Models 9.9/15, 9.9/15 Bigfoot (4-Stroke), August 1998.
  - Service Manual, Models 40, 50, 55, 60, January 1998.
  - Service Manual, Models 4, 5 (4-Stroke), January 1999.
  - Service Manual, Models V-300, V-3.4 Litre, 1984.
  - Service Manual, Remote Controls, September 1998.
  - Service Manual, Power Steering, 1996.
- Outboard Marine Corporation (OMC). Service manuals used in the development of this unit include:
  - 1999 EE 60° LV Service Manual
  - 1999 EE 90° LV Service Manual
  - 1999 EE 40 thru 70 Service Manual
  - 1999 EE 25, 35 Service Manual 3-Cylinder
  - 1999 EE 9.9 thru 30 Service Manual
  - 1999 EE 2 thru 8 Service Manual
  - 1999 EE 60° V4, V6 FFI Service Manual
  - 1999 EE 90° V6 FFI Service Manual
  - 1999 EE 70 4-Stroke Service Manual
  - 1999 EE 5 thru 15 4-Stroke Service Manual
  - 1999 EE Accessories Service Manual
- *Outboard Repair.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1985.
- *Parts Catalog: Model TOB-300.* Tanaka, 1998.

Suggested Activities

- Sherman, Edwin R. *Outboard Engines: Maintenance, Troubleshooting, and Repair.* Camden, Maine: International Marine, a division of The McGraw-Hill Companies, 1997.

- United States Coast Guard. *Skipper's Safe Boating Course,* 2nd ed. St. Louis, Missouri: Mosby-Year Book, Inc.. 1996.

Suggested supplemental resources

Print media

- *Boating Magazine.* 1633 Broadway, New York, New York 10019, (212) 767-5585.

- *Motor Boating and Sailing* magazine. 250 W. 55th St., New York, New York 10019, (212) 649-4099.

- *Trailer Boats* magazine. Poole Publications, Inc., 20700 Belshaw Ave., Carson, California 90746-3510, (310) 537-6322.

- Service manuals and operator's manuals for systems and equipment covered in this unit. Available from equipment manufacturers.

- Parts catalogs for systems covered in this unit. Available from equipment manufacturers.

Nonprint media

- Small-engine video series. Each of these 15-minute VHS programs covers the title topics and carries 1993 and 1994 copyrights. The first program includes information about outboard engines, as well as other types of power product equipment. The remaining programs use Briggs and Stratton 3- and 5-hp engines as examples, but of course, many of the principles apply to outboard engines. The videotapes are available from Shopware, P.O. Box 2708, Charleston, West Virginia 25330, (800) 487-3392. Available titles include:

  - The Basics
  - Four-Stroke-Engine Operation
  - Engine Disassembly
  - Engine Reassembly
  - Completing the Reassembly
  - Fuel-System Diagnosis
  - Ignition-System Diagnosis
  - Systems Diagnosis
  - Maintenance and Storage
  - Two-Stroke-Engine Operation
  - Two-Stroke-Engine Disassembly
  - Two-Stroke-Engine Assembly
  - Two-Cycle-Engine Troubleshooting
  - Servicing and Storing Two-Cycle Engines

- *Outboard Motors.* This VHS program discusses safety in outboard-engine operation as well as maintenance for the power head and lower unit. Available from Shopware.

Suggested Activities

- *Multimedia Small Engines.* These 1998 CD-ROM programs come in three parts that combine video, animation, text, and photos to discuss operation and service of small engines for computers running Windows. The first program covers engine design and the ignition system. The second program discusses lubrication, cooling, speed control, and fuel systems. The final program focuses on fault diagnosis and overhaul. Available from Shopware.

Organizations

- National Marine Manufacturers Association. A good source of information about trends in watercraft sales and production. 200 E. Randolph Drive, Suite 5100, Chicago, Illinois 60601, (312) 946-6200, website http://www.nmma.com.

- Association of Marine Technicians (AMTECH). An organization dedicated to improving marine service through cooperation, certification, and education. 455 Knollwood Terrace, Roswell, Georgia 30075-3416, (800) 467-0982.

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Operation and Service of Power-Output Systems
Unit 3

Answers to Assignment Sheets

Assignment Sheet 1—The correct answers will vary depending on the specific engine referenced, and may vary depending on model year, serial number, emissions equipment, engine configuration, intended application, and other factors. Instructors should accept answers based on the reference materials available to the students.

Assignment Sheet 2

1. c
2. c
3. c
4. c
5. b

Assignment Sheet 3

1. 3 : 1
2. 1.5 : 1
3. 1 : 1
4. 1.75 : 1
5. ½ : 1

Assignment Sheet 4—The correct answers will vary depending on the specific engine referenced, and may vary depending on model year, serial number, emissions equipment, engine configuration, intended application, and other factors. Instructors should accept answers based on the reference materials available to the students.

Operation and Service of Power-Output Systems
Unit 3

Answers to Written Test

1. The purpose of an outboard engine is to apply the power produced by the engine in such a way that work is accomplished. In the case of an outboard engine, the work to be done is the movement of a boat across water. Therefore, the engine output must be directed in such a way that power is applied to moving the boat.

   The transfer of power is done through the drive train, which consists of the drive shaft in the midsection and the gearcase and propeller assembly in the lower unit.

   Some designs will also include mechanisms for shifting the direction or speed of propeller rotation or the angle of the propeller blades.

2. a. 6
   b. 2
   c. 8
   d. 9
   e. 1
   f. 4
   g. 5
   h. 7
   i. 3

3. Answers may appear in any order.
   - Nonshifting
   - Mechanical shifting

4. a. pinion gear
   b. gear ratio
   c. shift linkage
   d. drive gear
   e. bearing assembly
   f. propeller
   g. propeller; clutch

5. a. 3
   b. 1
   c. 4
   d. 2
   e. 6
   f. 5
   g. 7
   h. 8
   i. 9

6. Answers may appear in any order.
   - Cast aluminum
   - Stainless steel
   - Plastic
   - Cast bronze

Answers to Written Test

7. Blades are set at an angle on the propeller.

   The propeller turns in such a way that water flows from the leading edge of the blade to the trailing edge of the blade with increasing speed.

   The normal rotation of the propeller is such that water will flow from the front of the blade to the rear of the blade.

   In North America, normal rotation of the propeller is clockwise when the mounted engine is viewed from behind the stern of the boat.

   Counter-rotation is a counterclockwise rotation of the propeller—rotation in the opposite direction of normal rotation.

8. a. Metal or plastic
   b. Fixed or dynamic

9. a. Propeller blades with a blade angle that is no longer at the angle of manufacture; a defect caused by the twisting of the blade material

   b. Propeller blades with a reduced diameter or thrust area due to the friction created as the blades rotate through the water

   c. Propeller blades with small pieces broken off the blade edges

   d. Propeller blades with small, nearly invisible cracks in the blade material or at the joints where the blades join the hub

   e. Propeller blades with large pieces broken off

   f. Propeller with blades that have broken off

   g. Propeller blades with a blade angle no longer at the angle of manufacture; a defect caused by the lateral bending of the blade material

   h. Propeller blades with pitting or crusty deposits as a result of the chemical action of oxygen, water, and acids

   i. Propeller blades with pitting, discoloration, flaking metal, or other symptoms of the excessive buildup of electrical charge and the results of exposure to acids

   j. Propeller hub with an overly large bore or splines, allowing play in the propeller as it rotates

10. a. Ensure that the propeller is properly identified so that it can be matched to the correct boat when it is returned.

    b. Identify the known defects so that the repair facility will be sure to correct those defects during the repair process.

c. Use a facility that can be trusted to give an honest evaluation of the propeller condition and that can do quality repairs.

d. Have the facility commit to a return date.

e. Coordinate the return date, cost, and processes to be performed with the customer and get the customer to approve the work.

f. Pack the propeller in such a way that it will not receive additional damage during shipping and handling.

g. Use a reputable shipping agent.

h. Follow up with the repair facility to ensure that the work is proceeding, to determine whether additional processes are necessary, and to determine that the return date is still valid.

i. Inspect the propeller upon return from the facility to ensure the quality of work, and notify the customer of the results of your inspection.

11. Answers may appear in any order.

- Do not operate the engine without the lower unit's being submerged.

- If the engine exhaust is not below water level, operate the engine only with adequate ventilation or exhaust removal.

- Do not operate the engine without the propeller and shafts being adequately secured.

- Do not place your hands or other objects into the water near an operating propeller.

- Disconnect the spark-plug leads prior to servicing the propeller.

12. Answers may appear in any order.

- Propeller out of balance
- Weeds or debris in propeller or lower unit
- Binding of the lower unit
- Incorrect propeller
- Slippage of propeller hub
- Gearcase loose or worn linkage
- Incorrect trim-tab setting

13. Answers may appear in any order.

- Set the trim tab to offset the amount of walking.
- Offset the engine from the center of the transom.
- Use an engine that has the lower unit offset from center.
- Use two engines with propellers that rotate in opposite directions.
- Properly maintain the engine.

Operation and Service of Power-Output Systems
Unit 3

Written Test

Name ______________________ Score ______________

1. Describe the typical power-output systems used in outboard engines. Write your answer on the blank lines provided below.

2. Match the major components of power-output systems to their correct functions. Write the numbers on the blanks provided. Functions continue on the next page.

_____ a. Allows water from the cooling system and the engine exhaust gases to exit the engine

_____ b. Transfers the power from the engine to the lower unit

_____ c. Moves water from one side of its blades to the other to create movement of the boat

_____ d. Improves steering, helps provide even water flow past the propeller, and protects the propeller

_____ e. Protects the power-output-system components and determines the depth of the propeller

_____ f. Separates the submerged and above-water portions of the engine

_____ g. Offsets the flow of water produced by the propeller to overcome torque forces that would cause the boat to veer to one side

1. Housing
2. Drive shaft
3. Shift rod
4. Antiventilation plate
5. Trim tab
6. Exhaust port
7. Gearcase
8. Propeller
9. Skeg

Written Test

______ h. Houses the gears that transmit power from the drive shaft to the propeller

______ i. Transfers the mechanical force from the shift control to engage the forward or reverse gears with the propeller shaft

3. List the design features used to classify power-output systems. Write your answers on the blank lines provided below.

   a. ____

   b. ____

4. Complete statements about the principles of operation of mechanical-shifting power-output systems. Write your answers on the blanks provided in the statements below.

   a. The ______________ of the drive shaft meshes with gears in the gearcase.

   b. The gearcase changes the direction and often the ______________ of the power transfer from the engine.

   c. The ______________ positions the gears along the propeller shaft so that the forward gear, reverse gear, or neither gear is engaged with the propeller shaft.

   d. The ______________ engages the propeller shaft and causes it to rotate.

   e. The propeller shaft is supported by a ______________ to provide reduced friction and good alignment.

   f. The ______________ is fastened to the propeller shaft and rotates as it turns.

   g. A protective device usually joins the ______________ to the shaft or the ______________ to the shaft.

5. Match the major components of outboard-engine propeller assemblies to their correct functions. Write the numbers on the blanks provided. Assemblies and functions continue on the next page.

______ a. Supports the blades and forms a housing for the hub, shaft, bearings, and other components

______ b. Prevents water from entering the gearcase

______ c. Moves water from one side of the propeller to the other

______ d. Protects the propeller and lower unit in case the propeller strikes a submerged object

1. Seal
2. Shear pin
3. Propeller body
4. Blade

Written Test

_______ e. Keeps the propeller from sliding off the shaft

_______ f. Mates the propeller to the shaft

_______ g. Covers the end of the propeller shaft

_______ h. Supports the propeller shaft and reduces the friction from rotation

_______ i. Transmits force from the engine to turn the propeller

5. Hub
6. Fastener
7. Spinner
8. Bearing
9. Propeller shaft

6. List the materials used in the manufacture of outboard-engine propellers. Write your answers on the blank lines provided below.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

7. Describe the principles of propeller rotation and counter-rotation. Write your answer on the blank lines provided below.

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

8. List the design features used to classify propeller hubs. Write your answers on the blank lines provided below.

   a. Construction material used ______________________________

   b. Hub configuration ______________________________

Written Test

9. Define types of propeller defects. Write your answers on the blank lines provided beside the terms below.

   a. Warped blades ______________________

   b. Worn blades ______________________

   c. Nicked blades ______________________

   d. Blades with stress fractures ______________________

   e. Broken blades ______________________

   f. Missing blades ______________________

   g. Bent blades ______________________

   h. Corroded blades ______________________

   i. Electrolytic deterioration ______________________

   j. Worn propeller hub ______________________

10. Complete guidelines for sending a propeller to a repair facility. Write the complete guideline on the blank lines provided beside each of the phrases below and on the next page.

    a. Properly identified ______________________

    b. Known defects ______________________

c. Trusted facility

d. Return date

e. Coordinate with the customer

f. Pack the propeller

g. Shipping agent

h. Follow up

i. Inspect the propeller

11. State safety rules for servicing power-output systems. Write your answers on the blank lines provided below.

a.

b.

c.

d.

e.

Written Test

12. List the probable causes of poor boat performance related to power-output systems. Write your answers on the blank lines provided below.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

13. List methods used to compensate for walking. Write your answers on the blank lines provided below.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

Permission to duplicate this test is granted.

Operation and Service of Power-Output Systems
Unit 3

Unit Evaluation Form

Student name ________________________ Unit rating ____________

Assignment-sheet ratings

Assignment Sheet 1—Determine Parts and Specifications for Power-Output Systems Rating ______

Comments: ____

____

Assignment Sheet 2—Interpret a Power-Output-System Troubleshooting Chart Rating ______

Comments: ____

____

Assignment Sheet 3—Calculate Gear Ratios Rating ______

Comments: ____

____

Assignment Sheet 4—Determine Correct Propeller Characteristics for Specific Applications Rating ______

Comments: ____

____

Job-sheet ratings

Job Sheet 1—Perform Routine Maintenance on Power-Output Systems Rating ______

Comments: ____

____

Job Sheet 2—Repair Power-Output Systems Rating ______

Comments: ____

____

Unit Evaluation Form

Job Sheet 3—Remove and Replace Propellers Rating ______

Comments: ____________________

Job Sheet 4—Check RPM on Propellers Rating ______

Comments: ____________________

Job Sheet 5—Perform Failure Analysis on Power-Output-System Components Rating ______

Comments: ____________________

Written-test scores

Pretest ______ Posttest ______ Other ______

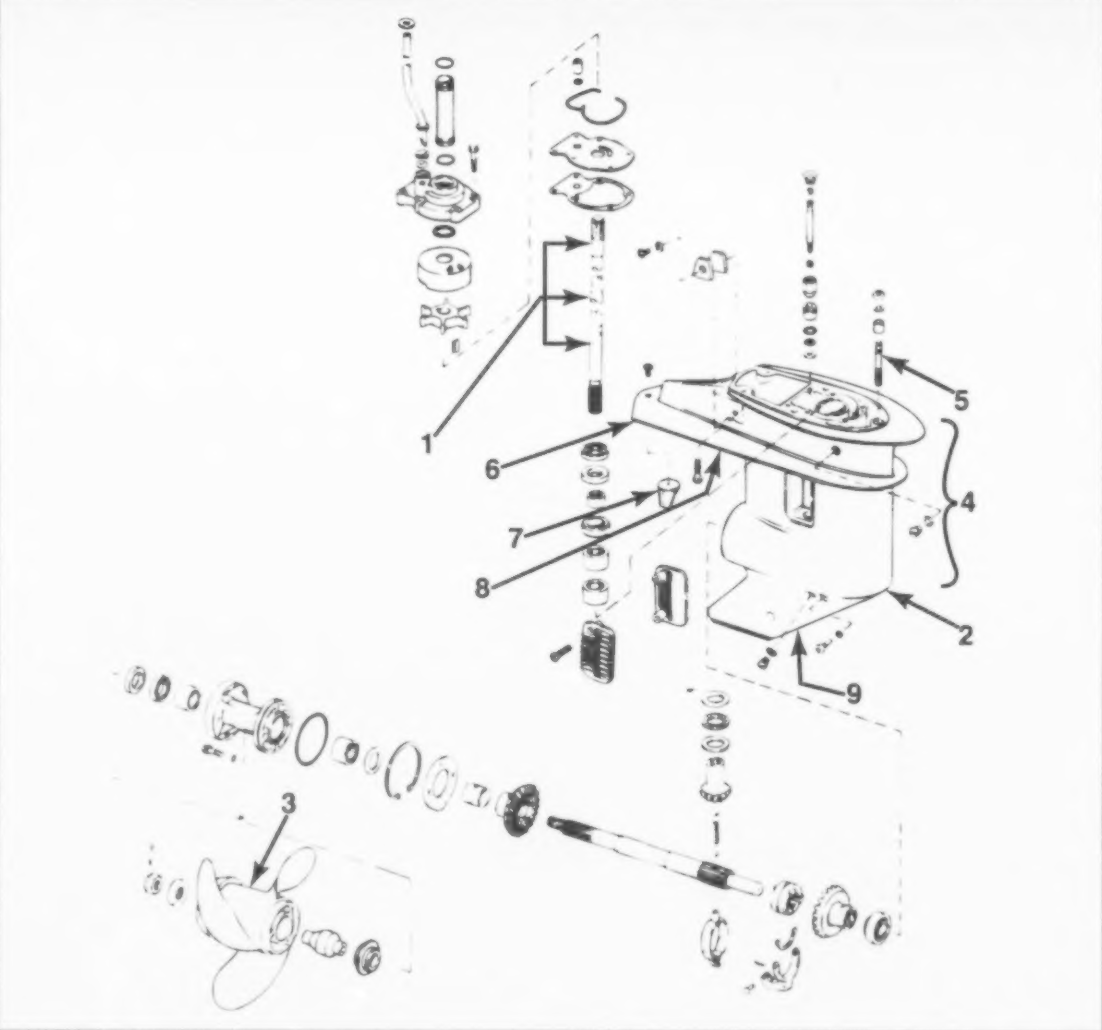
Comments: ____________________

Teacher signature ____________________ Date ______

Student signature ____________________ Date ______

Permission to duplicate this form is granted.

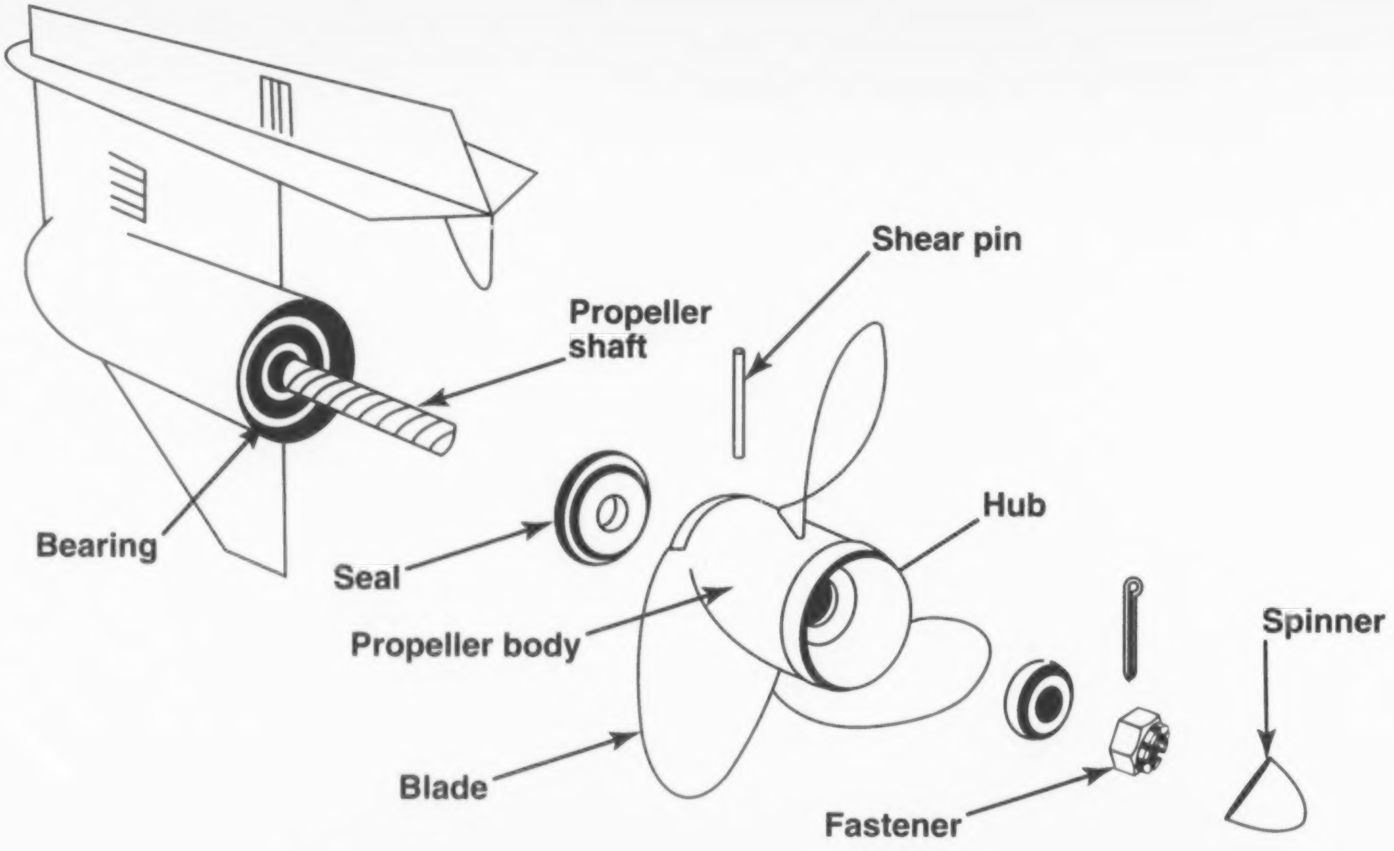
Major Components of Power-Output Systems



1. Drive shaft
2. Gearcase
3. Propeller assembly
4. Housing
5. Shift rod
6. Antiventilation plate
7. Trim tab
8. Exhaust port
9. Skeg

Reprinted with permission of Outboard Marine Corporation (OMC), Waukegan, Illinois.

Major Components of Propeller Assemblies


Shear pin
Propeller shaft
Hub
Bearing
Seal
Propeller body
Spinner
Blade
Fastener

Job Sheet 1

Worksheet—Perform Routine Maintenance on Power-Output Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

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Instructor's signature ______________________

Job Sheet 1

Worksheet—Perform Routine Maintenance on Power-Output Systems

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Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 2

Worksheet—Repair Power-Output Systems

Name ______________________________ Attempt number ____________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 2

Worksheet—Repair Power-Output Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 3

Worksheet—Remove and Replace Propellers

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 3

Worksheet—Remove and Replace Propellers

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 4

Worksheet—Check RPM on Propellers

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ____

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 4

Worksheet—Check RPM on Propellers

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

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Job Sheet 5

Worksheet—Perform Failure Analysis on Power-Output-System Components

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 5

Worksheet—Perform Failure Analysis on Power-Output-System Components

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Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Control and Safety Systems
Unit 4

Suggested Activities

Instructional plan

Preparation

- Review the unit in the student edition and plan your presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review the unit introduction and teaching suggestions included in the delivery and application section below, and plan classroom activities. Also note suggestions for media and supplemental materials.

  Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.

- Prepare the classroom by displaying posters, equipment, and tools related to outboard-engine control and safety systems.
- Make transparencies from the transparency masters included in the teacher pages of this unit.
- Select teacher components (written test, unit evaluation form) you want to distribute to your students. Copy and prepare these components for distribution.
- Review the job sheets and worksheets in the student edition and locate the worksheet masters included in the teacher pages of this unit. Copy and prepare extra worksheets for distribution to your students.

Delivery and application

Unit introduction

The skill areas appearing in bold-face type in the unit introduction and teaching suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want*. These have been adapted by MAVCC.

- Provide students with copies of the student materials. You may choose to begin by discussing the objective sheet. Review the unit and specific objectives with the students. Discuss how meeting the unit objective will improve their employability or will increase their value as an employee. Explain how the specific objectives support the unit objective. **(Listening; adapting to the organization's traditional modes of operation; emphasizing personal and career development)**
- Introduce the unit by discussing boating dangers. Have a visitor share a mishap or have a member of the class share a mishap that resulted from a loss of control of a boat. Discuss ways in which the accident could have been prevented and relate the discussion to safety and control features built into many outboard-engine systems. Have the students think about differing safety requirements between boats and

cars. For example, cars have spring-loaded accelerator pedals so that if the driver's foot is removed from the pedal, less fuel flows to the engine and the car will tend to slow down. Boats, on the other hand, generally have throttles that remain fixed in place unless moved by the operator. Thus, if the operator were to become incapacitated, the engine would continue to receive the same amount of fuel and a boat traveling at 30 mph would continue to speed across the water. **(Listening; reasoning; seeing things in the mind's eye; system interrelationships)**

Teaching suggestions

Objective 1 Define the terms *control system* and *safety system*.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use a model boat or other prop to demonstrate the control of a boat and then display control systems for affecting changes in the listed characteristics of boat performance. Continue the discussion by explaining how safety systems can be useful in preventing operation of the boat that could lead to damage to the boat or injury to the passengers. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information)**

Objective 2 State the functions of the types of control systems used with outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use illustrations, models, or actual boats to discuss the common outboard-engine control systems. Relate these controls to engine-support systems, such as fuel and ignition systems. Demonstrate the operation of each and explain its effects on the boat. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information)**

Objective 3 Define the classifications of outboard-engine control systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Provide the students with examples of both on-engine and remote-control systems of various designs and involving the various types of control systems. Exhibit different types of linkages used with remote-control systems. Discuss associated service procedures, including installation considerations. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

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Suggested Activities

Objective 4 Define the types of steering systems used with outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Use the artwork in Figures 1 through 3 in the information sheet and Transparencies 1 through 3 to illustrate your discussion. Also, exhibit examples of each type of steering system. Explain the operation of each and compare and contrast them. Discuss the advantages and disadvantages of each steering system for specific boat applications. Discuss service procedures associated with each design. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 5 Define the terms *tilt, trim,* and *trim tab.*

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Operate a tilt and trim system and adjust a trim tab to help students conceptualize these control functions. Explain common distinctions between tilt and trim in terms of angle, using 20- to 30-degree limits for trim, or a standard preferred by your program. Explain the purpose of these control functions and the various ways in which they are implemented. Discuss common service procedures and associated safety considerations. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information)**

Objective 6 Describe the effect of trim tab on boat performance.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Use models to demonstrate the effects of trim-tab positioning on boat performance. Discuss the forces acting upon a boat. Show various types of trim-tab designs. Discuss the effects on boat performance resulting from damaged trim tabs. Associate these concepts with customer complaints about boat performance so that the students understand that some customer complaints may be the result of improper trim-tab adjustment. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 7 List the purposes of the trim tab.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**
- Emphasize auxiliary functions of trim tabs, such as the sacrificial anode and exhaust-port functions. Exhibit a variety of trim-tab designs, including those used for a variety of functions. Demonstrate the effects of trim-tab positioning to the extent necessary to ensure that students understand them. **(Listening; reasoning; seeing things in the mind's**

eye; interpreting and processing information; system interrelationships)

Objective 8 State the purposes of the types of hydraulic circuits used in outboard-engine control systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Provide examples of boats with hydraulic systems. Review the principles of hydraulics to the extent necessary to allow students to understand the function of tilt and steering systems. Review hydraulic-circuit diagrams and explain their interpretation. Discuss the selection and use of hydraulic fluids, as well as precautions in handling hydraulic fluids and working with hydraulic systems. Demonstrate service procedures. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 9 List the types of hydraulic cylinders used in outboard-engine control systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use the artwork in Figure 4 in the information sheet, Transparency 4, and examples of both types of hydraulic cylinders to illustrate your discussion. Relate both types to specific applications. Compare and contrast the two types. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 10 List the types of hydraulic fluids used in tilt and trim systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Provide the students with examples of each type of hydraulic fluid and with service manuals that specify hydraulic fluids for specific applications. Emphasize those fluids formulated for marine use. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 11 Complete guidelines for filling hydraulic systems.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Describe and demonstrate typical procedures performed when servicing hydraulic systems. Emphasize safety precautions and those guidelines intended to prevent damage to the boat. Show the students ways in which fluid levels are determined and discuss conditional requirements, such as whether or not the engine should be running, the fluid should be warm, the position of controls when checking fluid levels or servicing the system, etc. Demonstrate bleeding the system and explain the purpose of doing so. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 12 Match the major components of remote-control assemblies to their correct functions.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use the artwork in Figure 5 in the information sheet, Transparency 5, and other illustrations, models, or actual equipment to provide the students with a variety of remote-control designs. Emphasize functions that are available on virtually all remote-control systems and those that may be found on limited numbers of systems. Demonstrate and discuss associated service procedures. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information)**

Objective 13 State functions of the safety systems used with outboard engines.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Use actual equipment to show the location of and describe the functioning of the various types of safety systems. Explain how each type works in terms of boat operation and operator actions. Discuss the need for sacrificial anodes. Exhibit boat damage caused by corrosion. Discuss various methods of providing corrosion protection. Demonstrate service procedures associated with safety systems. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Objective 14 Complete statements about the principles of operation of emergency-stop lanyards.

- Read and discuss with students the information presented in this section of the information sheet. **(Reading/listening for content)**

- Expand your discussion of safety systems by detailing the operation of the emergency-stop lanyard. Show a variety of designs and demonstrate the use and operation of each type. Discuss possible problems and likely indications that the lanyard system is not functioning properly. **(Listening; reasoning; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

Assignment Sheet 1 Determine control-system and safety-system service specifications and parts requirements.

- Have students locate Assignment Sheet 1. Read the introduction and directions to the assignment. **(Reading/listening for direction)**

Suggested Activities

- Make resources available that will allow the students to determine the required information. Tailor the assignment sheet to equipment used in your facility. **(Reading; writing; seeing things in the mind's eye; acquiring, organizing, interpreting, and processing information; system interrelationships)**

- Answer any student questions and have students complete Assignment Sheet 1.

Job Sheet 1 Perform routine maintenance on steering systems.

- Have students locate Job Sheet 1 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on steering systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an outboard-engine boat with a steering system and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 1.

Job Sheet 2 Repair steering systems.

- Have students locate Job Sheet 2 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing steering systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an outboard-engine boat with a steering system that requires repair and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 2.

Job Sheet 3 Perform routine maintenance on tilt and trim systems.

- Have students locate Job Sheet 3 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on tilt and trim systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an outboard-engine boat with a tilt and trim system and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 3.

Job Sheet 4 Repair tilt and trim systems.

- Have students locate Job Sheet 4 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing tilt and trim systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.

- Provide students with an outboard-engine boat with a trim and tilt system to be repaired and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 4.

Job Sheet 5 Perform routine maintenance on remote-control systems.

- Have students locate Job Sheet 5 and the worksheet associated with the job sheet. Demonstrate the procedures for performing routine maintenance on remote-control systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an outboard-engine boat with a remote-control system and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 5.

Job Sheet 6 Repair remote-control systems.

- Have students locate Job Sheet 6 and the worksheet associated with the job sheet. Demonstrate the procedures for repairing remote-control systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an outboard-engine boat with a remote-control system to be repaired and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 6.

Job Sheet 7 Service safety systems.

- Have students locate Job Sheet 7 and the worksheet associated with the job sheet. Demonstrate the procedures for servicing safety systems. Review with students the worksheet associated with the job sheet, and have them obtain copies of the worksheet for each attempt that will be required.
- Provide students with an outboard-engine boat with safety systems and have them complete the pre-performance check (Part A) on the worksheet. Evaluate the pre-performance check, and when a student has completed it satisfactorily, have him/her complete Job Sheet 7.

Evaluation

- Evaluate the assignment sheet. See the evaluation criteria listed at the top of the assignment sheet as well as the teacher page "Answers to Assignment Sheet."

Suggested Activities

- Evaluate the job sheets.

When the student is ready to perform a specific task, obtain a copy of the worksheet associated with each job sheet. Worksheets may be found in the student edition and in the teacher pages. Then, observe the student performing the procedure.

After the student has completed the procedure, rate the student using the criteria provided on the worksheet. If the student's performance is unacceptable, have the student review the materials and perform the procedure again for evaluation.

Two sample performance evaluation keys are provided below. Many other keys are available. Select one evaluation key (grading scale) that best fits your program needs.

Performance Evaluation Keys

Sample A

4 — Skilled—Can perform job with no additional training.
3 — Moderately skilled—Has performed job during training program; limited additional training may be required.
2 — Limited skill—Has performed job during training program; additional training is required to develop skill.
1 — Unskilled—Is familiar with process, but is unable to perform job.

Sample B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

- Give the written test. See the teacher page "Written Test."
- Evaluate the written test. See the teacher page "Answers to Written Test."
- Compile written-test, assignment-sheet, and job-sheet scores. See the teacher page "Unit Evaluation Form."
- Reteach and retest as required.

Suggested resources

Resources used in developing this unit

Print media

- Buchanan, George. *The Boat Repair Manual.* New York: Arco Publishing, Inc., 1985.

Suggested Activities

- *Everything You Need to Know About Propellers,* 4th ed. Brunswick Corporation, 1992.
- Gladstone, Bernard, and Tom Bottomley. *Boatkeeper: The Boatowner's Guide to Maintenance, Repair, and Improvement.* New York: Hearst Marine Books, 1984.
- Kendall, Dave. *The Complete Book of Boat Maintenance and Repair.* Garden City, New York: Doubleday and Company, Inc., 1975.
- Mercury Marine. Service manuals used in the development of this unit include:
  - — Accessories Parts Catalog, 1998.
  - — Service Manual, Models 135, 150, 175, 200, 225, September 1997.
  - — Service Manual, Models 9.9/15, 9.9/15 Bigfoot (4-Stroke), August 1998.
  - — Service Manual, Models 40, 50, 55, 60, January 1998.
  - — Service Manual, Models 4, 5 (4-Stroke), January 1999.
  - — Service Manual, Models V-300, V-3.4 Litre, 1984.
  - — Service Manual, Remote Controls, September 1998.
  - — Service Manual, Power Steering, 1996.
- Outboard Marine Corporation (OMC). Service manuals used in the development of this unit include:
  - — 1999 EE 60° LV Service Manual
  - — 1999 EE 90° LV Service Manual
  - — 1999 EE 40 thru 70 Service Manual
  - — 1999 EE 25, 35 Service Manual 3-Cylinder
  - — 1999 EE 9.9 thru 30 Service Manual
  - — 1999 EE 2 thru 8 Service Manual
  - — 1999 EE 60° V4, V6 FFI Service Manual
  - — 1999 EE 90° V6 FFI Service Manual
  - — 1999 EE 70 4-Stroke Service Manual
  - — 1999 EE 5 thru 15 4-Stroke Service Manual
  - — 1999 EE Accessories Service Manual
- *Outboard Repair.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1985.
- *Parts Catalog: Model TOB-300.* Tanaka, 1998.
- Sherman, Edwin R. *Outboard Engines: Maintenance, Troubleshooting, and Repair.* Camden, Maine: International Marine, a division of The McGraw-Hill Companies, 1997.
- United States Coast Guard. *Skipper's Safe Boating Course,* 2nd ed. St. Louis, Missouri: Mosby-Year Book, Inc., 1996.

Suggested Activities

Suggested supplemental resources

Print media

- *Boating Magazine*. 1633 Broadway, New York, New York 10019, (212) 767-5585.

- *Motor Boating and Sailing* magazine. 250 W. 55th St., New York, New York 10019, (212) 649-4099.

- *Trailer Boats* magazine. Poole Publications, Inc., 20700 Belshaw Ave., Carson, California 90746-3510, (310) 537-6322.

- Service manuals and operator's manuals for systems and equipment covered in this unit. Available from equipment manufacturers.

- Parts catalogs for systems covered in this unit. Available from equipment manufacturers.

Nonprint media

- Small-engine video series. Each of these 15-minute VHS programs covers the title topics and carries 1993 and 1994 copyrights. The first program includes information about outboard engines, as well as other types of power product equipment. The remaining programs use Briggs and Stratton 3- and 5-hp engines as examples, but of course, many of the principles apply to outboard engines. The videotapes are available from Shopware, P.O. Box 2708, Charleston, West Virginia 25330, (800) 487-3392. Available titles include:

    — The Basics
    — Four-Stroke-Engine Operation
    — Engine Disassembly
    — Engine Reassembly
    — Completing the Reassembly
    — Fuel-System Diagnosis
    — Ignition-System Diagnosis
    — Systems Diagnosis
    — Maintenance and Storage
    — Two-Stroke-Engine Operation
    — Two-Stroke-Engine Disassembly
    — Two-Stroke-Engine Assembly
    — Two-Cycle-Engine Troubleshooting
    — Servicing and Storing Two-Cycle Engines

- *Outboard Motors.* This VHS program discusses safety in outboard-engine operation as well as maintenance for the power head and lower unit. Available from Shopware.

- *Multimedia Small Engines.* These 1998 CD-ROM programs come in three parts that combine video, animation, text, and photos to discuss operation and service of small engines for computers running Windows. The first program covers engine design and the ignition system. The second program discusses lubrication, cooling, speed control, and fuel systems. The final program focuses on fault diagnosis and overhaul. Available from Shopware.

Suggested Activities

Organizations

- National Marine Manufacturers Association. A good source of information about trends in watercraft sales and production. 200 E. Randolph Drive, Suite 5100, Chicago, Illinois 60601, (312) 946-6200, website http://www.nmma.com.

- Association of Marine Technicians (AMTECH). An organization dedicated to improving marine service through cooperation, certification, and education. 455 Knollwood Terrace, Roswell, Georgia 30075-3416, (800) 467-0982.

Operation and Service of Control and Safety Systems
Unit 4

Answers to Assignment Sheet

Assignment Sheet 1—The correct answers will vary depending on the specific engine referenced, and may vary depending on model year, serial number, emissions equipment, engine configuration, intended application, and other factors. Instructors should accept answers based on the reference materials available to the students.

Operation and Service of Control and Safety Systems
Unit 4

Answers to Written Test

1. a. System that allows the operator to adjust different aspects of the engine's operation or position, such as engine speed, the direction of propeller rotation, the gearcase setting, tilt and trim, and other performance features

   b. System that prevents the operation of the engine or boat system during conditions when such operation might result in equipment damage or injury

2. a. Turns the engine flywheel to begin the internal-combustion process

   b. Prevents the spark from reaching the combustion chamber to end the internal-combustion process

   c. Adjusts the flow of fuel to the engine to increase or decrease engine speed

   d. Positions the gearcase gears to allow forward travel, reverse travel, or a neutral position

   e. Pivots the engine horizontally in order to change the direction of boat travel

   f. Adjusts the engine horizontally or the flow of the water stream from the engine to keep the boat traveling in a straight line to compensate for other forces acting on the boat

   g. Adjusts the engine vertically to change the depth of the propeller in the water or to move the engine out of the way of obstacles

3. a. Controls used to adjust the operation or position of the engine; the operator uses a control device that is located on the engine

   b. Controls used to adjust the operation or position of the engine; the operator uses a control device that is not located on the engine

4. a. Steering system that uses hydraulic fluid to provide power assistance in the turning of the engine

   b. Steering system that uses a cable that moves within a tube to transmit force mechanically from the steering column to the turning of the engine

   c. Steering system that uses a cable each end of which is attached to opposite sides of the engine so that rotation of the steering wheel pivots the engine to one side or the other

   d. Steering system that uses a reel attached to the steering column so that turning the steering wheel moves the actuating mechanism

   e. Steering system that uses a toothed metal bar that is free to move laterally in response to rotation of the steering column

Answers to Written Test

5. a. Engine movement in which the engine pivots to raise or lower the gearcase in order to protect the engine from damage in shallow water or to trailer the boat

   b. Engine movement in which the engine pivots to raise or lower the gearcase in order to maintain the most-efficient relationship between the propeller output and the surface of the water

   c. Small fin installed under the antiventilation plate aft of the propeller and used to offset torque and other engine forces

6. A portion of the trim-tab effect is used to offset engine torque. The bow moves in the direction toward which the trim tab is offset. The greater the trim-tab angle, the less force that is applied to driving the boat forward. The greater the trim-tab angle, the greater the turbulence that is developed in the water flow through the propeller.

7. Answers may appear in any order.

   - Offsets the effects of engine torque
   - Improves steering
   - May serve as a sacrificial anode
   - May serve as the exhaust port

8. a. Rotates the engine vertically

   b. Pivots the engine from side to side

9. Answers may appear in any order.

   - Integral cylinder
   - Nonintegral cylinder

10. Answers may appear in any order.

    - Engine oils
    - Automatic-transmission fluids
    - Specially formulated fluids

11. a. Use the correct fluid.
    b. Do not overfill the reservoir.
    c. Avoid introducing contaminants into the system.
    d. Bleed air from the system if required.
    e. Do not mix incompatible fluids.

12. a. 8
    b. 11
    c. 2
    d. 5
    e. 6
    f. 3
    g. 4
    h. 7
    i. 1
    j. 10
    k. 9

Answers to Written Test

13. a. Stops the flow of current to the spark plug in the event that the boat operator gets too far from the operator's seat

    b. Prevents the engine from starting when the propeller shaft is engaged to the drive shaft

    c. Stops the flow of current to the spark plug if the angle of the engine is too far from vertical

    d. Stops the flow of current to the spark plug in the event that the engine speed gets too high

    e. Allows manual operation of the hydraulic tilt and trim and steering systems in the event of a failure in the hydraulic system

    f. Serves as a disposable component of the engine that undergoes electrolytic deterioration so that other more-important and expensive components are less affected

14. a. A normally open safety switch on the engine or on the dash near the key switch keeps the ignition circuit open.

    b. The switch is closed by inserting one end of the lanyard into a slot on the switch, allowing the engine to start and run.

    c. The other end of the lanyard is attached to the operator.

    d. If the operator moves away from the safety switch farther than the reach of the lanyard, the lanyard disconnects from the switch, which is spring-loaded to open.

    e. When the switch opens, the ignition circuit is interrupted and the engine shuts down.

Operation and Service of Control and Safety Systems
Unit 4

Written Test

Name ______________________ Score __________

1. Define the terms *control system* and *safety system*. Write your answers on the blank lines provided beside the terms below.

   a. Control system ______________________

   b. Safety system ______________________

2. State the functions of the types of control systems used with outboard engines. Write your answers on the blank lines provided beside the terms below and on the next page.

   a. Starting system ______________________

   b. Stop system ______________________

   c. Throttle system ______________________

d. Shift control ______________________________

e. Steering system ______________________________

f. Trim-tab system ______________________________

g. Tilt/trim system ______________________________

3. Define the classifications of outboard-engine control systems. Write your answers on the blank lines provided beside the terms below.

a. On-engine controls ______________________________

b. Remote controls ______________________________

4. Define the types of steering systems used with outboard engines. Write your answers on the blank lines provided beside the terms below and on the next page.

a. Hydraulic ______________________________

b. Mounted cable ______________________________

c. Cable over pulley ______________________________

d. Rotary ______________________________

e. Rack and pinion ______________________________

5. Define the terms *tilt, trim,* and *trim tab.* Write your answers on the blank lines provided beside the terms below.

a. Tilt ______________________________

b. Trim ______________________________

c. Trim tab ______________________________

6. Describe the effect of the trim tab on boat performance. Write your answer on the blank lines provided below.

____

Written Test

7. List the purposes of the trim tab. Write your answers on the blank lines provided below.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

8. State the purposes of the types of hydraulic circuits used in outboard-engine control systems. Write your answers on the blank lines provided beside the terms below.

   a. Tilt ____________________

   b. Steering ____________________

9. List the types of hydraulic cylinders used in outboard-engine control systems. Write your answers on the blank lines provided below.

   a. ____________________

   b. ____________________

10. List the types of hydraulic fluids used in tilt and trim systems. Write your answers on the blank lines provided below.

    a. ____________________

    b. ____________________

    c. ____________________

11. Complete guidelines for filling hydraulic systems. Write the complete guideline on the blank lines provided beside each of the terms below.

    a. Correct fluid ____________________

    ____

    b. Filling reservoir ____________________

    ____

    c. Contaminants ____________________

    ____

    d. Air ____________________

    ____

    e. Mixing fluids ____________________

    ____

Written Test

12. Match the major components of remote-control assemblies to their correct functions. Write the numbers on the blanks.

_______ a. Holds the levers in a set position

_______ b. Enriches the fuel system for cold starting

_______ c. Holds the assembly components

_______ d. Engages the face cam to transfer motion between the cam and levers

_______ e. Provides the cable connection to the shift control

_______ f. Applies force to the throttle cam

_______ g. Changes the orbital movement of the throttle-control lever to a vertical movement of the control cable

_______ h. Allows the operator to position the levers

_______ i. Limits the throttle advance during warmup with the shifter in neutral

_______ j. Controls the flow of power to the starter and ignition

_______ k. Promotes movement of the lever against the detent spring

1. Neutral warmup lever
2. Remote-control housing
3. Throttle lever
4. Face cam
5. Cam follower
6. Shift lever
7. Control lever
8. Detent spring
9. Detent-spring roller
10. Ignition switch
11. Choke button

13. State functions of the safety systems used with outboard engines. Write your answers on the blank lines provided beside each of the phrases below and on the next page.

a. Emergency-stop lanyard ____

____

____

b. Neutral-safety switch ____

____

____

c. Tilt switch ____

____

____

d. Revolution limiter ____________________

e. Manual-release valve ____________________

f. Sacrificial anode ____________________

14. Complete statements about the principles of operation of emergency-stop lanyards. Write the complete statement on the blank lines provided beside each of the terms below.

    a. Normally open safety switch ____________________

    b. Switch is closed ____________________

    c. Lanyard is attached ____________________

    d. Lanyard disconnects ____________________

    e. Switch opens ____________________

Permission to duplicate this test is granted.

Operation and Service of Control and Safety Systems
Unit 4

Unit Evaluation Form

Student name ______________________________ Unit rating ____________

Assignment-sheet rating

Assignment Sheet 1—Determine Control-System and Safety-System Service Specifications and Parts Requirements Rating ________

Comments: ______________________________

____

Job-sheet ratings

Job Sheet 1—Perform Routine Maintenance on Steering Systems Rating ________

Comments: ______________________________

____

Job Sheet 2—Repair Steering Systems Rating ________

Comments: ______________________________

____

Job Sheet 3—Perform Routine Maintenance on Tilt and Trim Systems Rating ________

Comments: ______________________________

____

Job Sheet 4—Repair Tilt and Trim Systems Rating ________

Comments: ______________________________

____

Job Sheet 5—Perform Routine Maintenance on Remote-Control Systems Rating ________

Comments: ______________________________

____

Unit Evaluation Form

Job Sheet 6—Repair Remote-Control Systems Rating ________

Comments: ____

____

Job Sheet 7—Service Safety Systems Rating ________

Comments: ____

____

Written-test scores

Pretest ________ Posttest ________ Other ________

Comments: ____

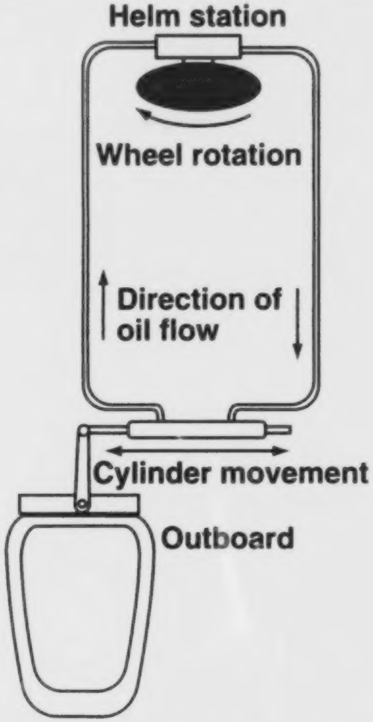
____

Teacher signature ____________________ Date ____________

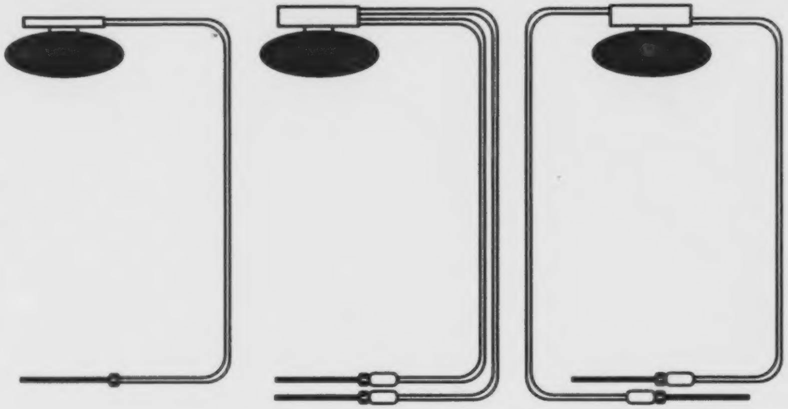
Student signature ____________________ Date ____________

Permission to duplicate this form is granted.

Types of Steering Systems:
Hydraulic and Mounted Cable


Helm station
Wheel rotation
Direction of oil flow
Cylinder movement
Outboard

Hydraulic steering system



Possible single-cable and dual-cable mounted-cable steering systems

Outboard-Engine Systems and Service, Unit 4
Teacher Page 189

TM 1

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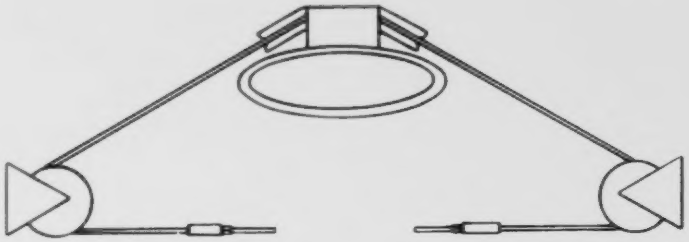
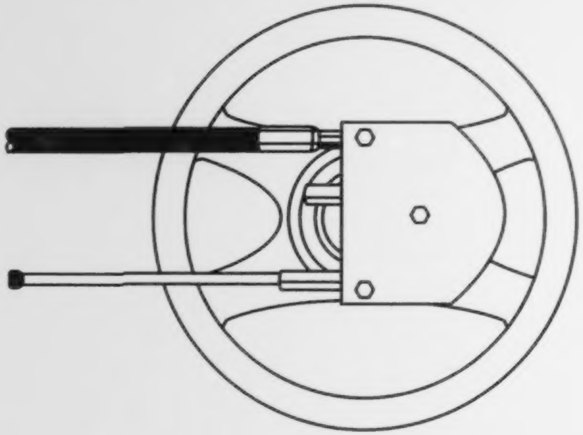
Types of Steering Systems:
Cable Over Pulley and Rotary



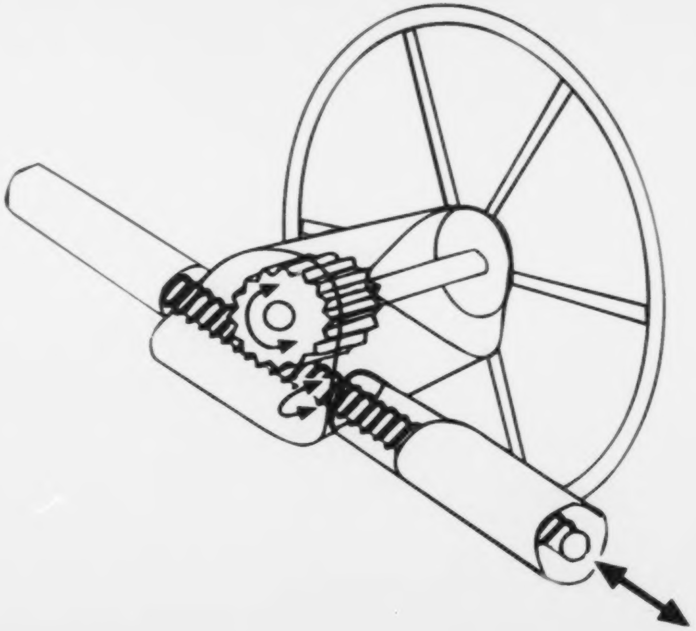
Cable-over-pulley steering system



Rotary steering system

"Rotary steering system" reprinted with permission of Mercury Marine, Fond du Lac, Wisconsin.

Types of Steering Systems:
Rack and Pinion



Rack-and-pinion steering system

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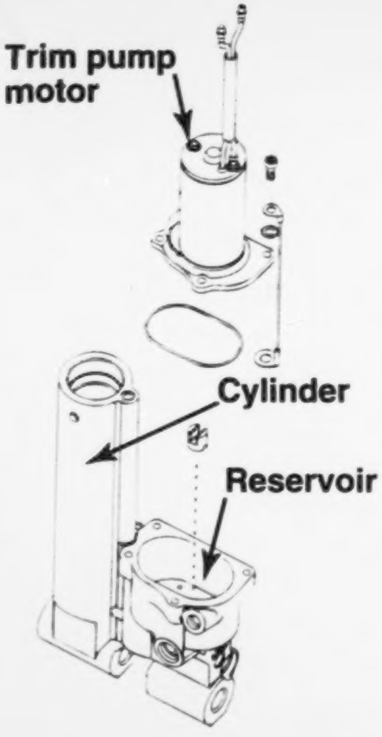
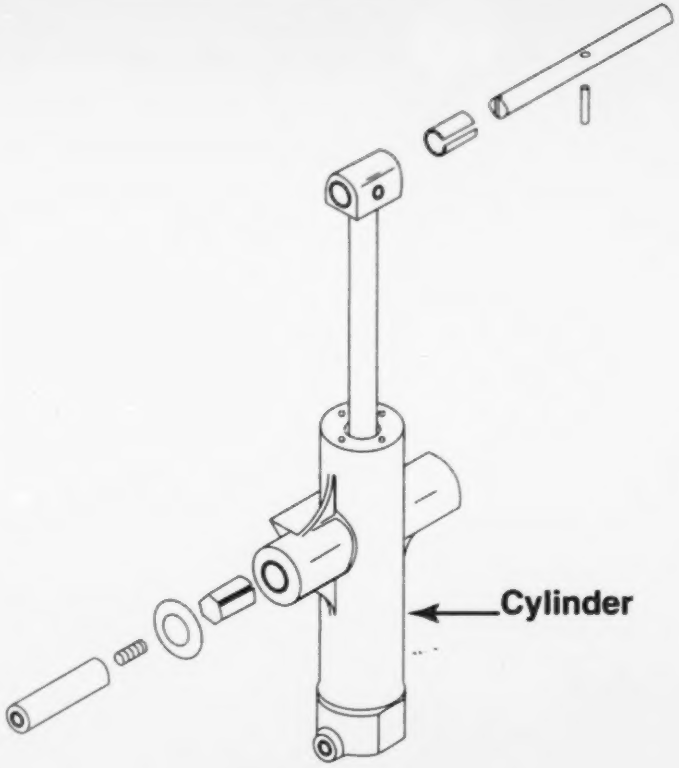
Types of Hydraulic-Cylinder Systems Used in Outboard-Engine Control Systems


Trim pump motor
Cylinder
Reservoir

Integral cylinder (Exploded view)



Nonintegral cylinder

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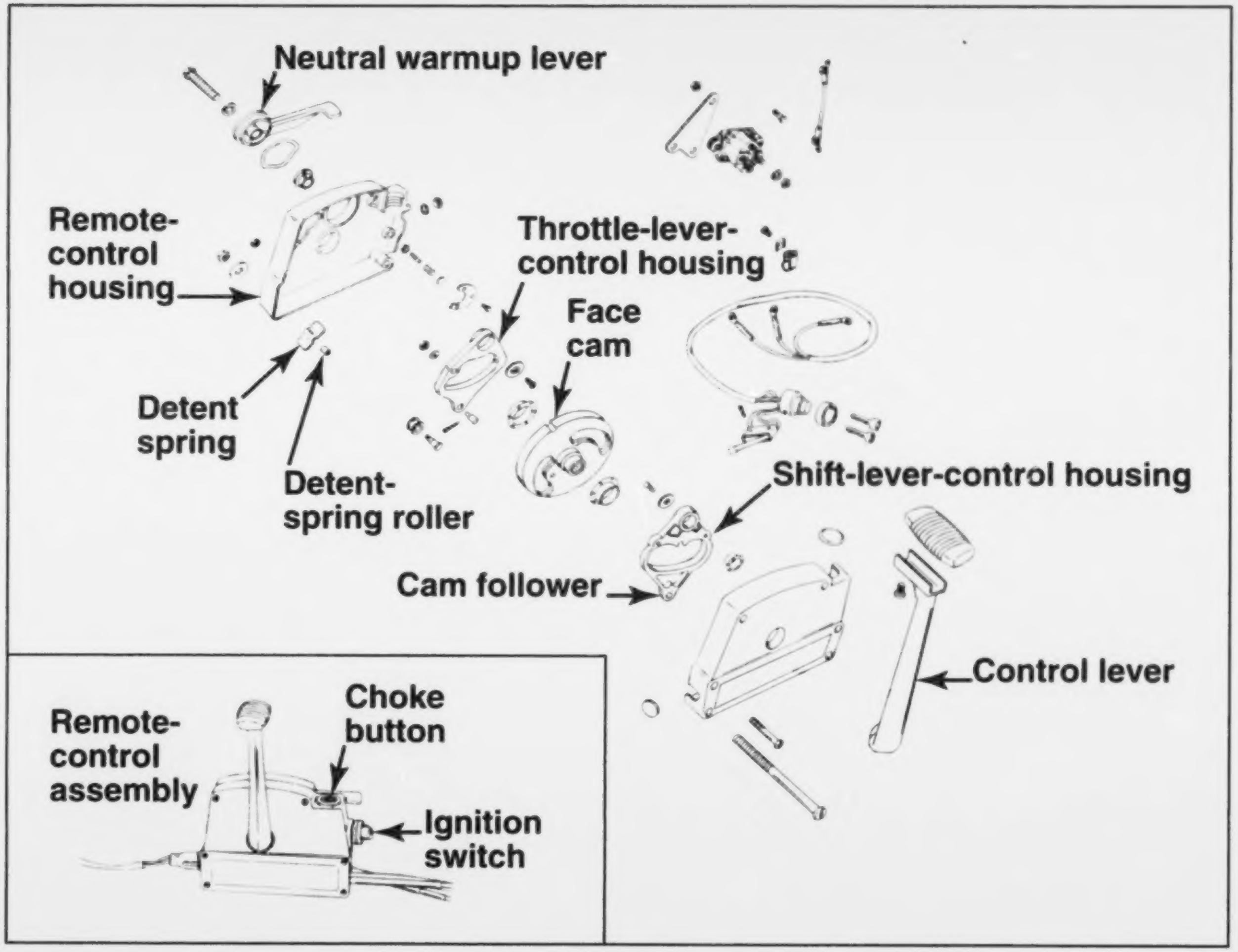
Major Components of Remote-Control Assemblies


Neutral warmup lever
Remote-control housing
Throttle-lever-control housing
Face cam
Detent spring
Detent-spring roller
Shift-lever-control housing
Cam follower
Control lever
Remote-control assembly
Choke button
Ignition switch

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Job Sheet 1

Worksheet—Perform Routine Maintenance on Steering Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 1

Worksheet—Perform Routine Maintenance on Steering Systems

Part B: Performance evaluation

Evaluation criteria **Rating**

Correct procedures identified for assigned equipment. ________

Procedures completed correctly. ________

Proper tools used correctly. ________

Safety precautions observed. ________

Service meets specifications. ________

Clean-up and follow-up actions adequate. ________

Overall rating ________

Evaluator's comments ____

____

____

Job Sheet 2

Worksheet—Repair Steering Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ____

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 2

Worksheet—Repair Steering Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	________
Procedures completed correctly.	________
Proper tools used correctly.	________
Safety precautions observed.	________
Service meets specifications.	________
Clean-up and follow-up actions adequate.	________
Overall rating	________

Evaluator's comments ____

____

____

Job Sheet 3

Worksheet—Perform Routine Maintenance on Tilt and Trim Systems

Name ____________________ Attempt number __________

Date ____________________

Part A: Pre-performance check

Job ____________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ____________________

  Equipment model/type and code ____________________

  ____

- Complete the following service-manual information.

  Service-manual title ____________________

  Section/page number of procedure ____________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ____________________

Worksheet—Perform Routine Maintenance on Tilt and Trim Systems

---

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 4

Worksheet—Repair Tilt and Trim Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 4

Worksheet—Repair Tilt and Trim Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	________
Procedures completed correctly.	________
Proper tools used correctly.	________
Safety precautions observed.	________
Service meets specifications.	________
Clean-up and follow-up actions adequate.	________
Overall rating	________

Evaluator's comments ____

____

____

Job Sheet 5

Worksheet—Perform Routine Maintenance on Remote-Control Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: **Pre-performance check**

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 5

Worksheet—Perform Routine Maintenance on Remote-Control Systems

---

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 6

Worksheet—Repair Remote-Control Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 6

Worksheet—Repair Remote-Control Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Job Sheet 7

Worksheet—Service Safety Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 7

Worksheet—Service Safety Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	________
Procedures completed correctly.	________
Proper tools used correctly.	________
Safety precautions observed.	________
Service meets specifications.	________
Clean-up and follow-up actions adequate.	________
Overall rating	________

Evaluator's comments ____

____

____

Power Product Equipment Technician Series

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Power Product Equipment Technician:

Outboard-Engine Systems and Service

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Outboard-Engine Systems and Service

Student Edition

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Outboard-Engine Design and Identification
Unit 1

Objective Sheet

Unit objective

After completing this unit, the student should be able to discuss engine-design characteristics and use these characteristics to identify types of outboard engines. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific objectives

After completing this unit, the student should be able to

1. List the characteristics used to identify outboard engines.
2. State the purposes of the major sections of outboard engines.
3. Match the major components of outboard engines to their correct functions.
4. Describe the combustion cycle of two-stroke-cycle outboard engines.
5. Describe the combustion cycle of four-stroke-cycle outboard engines.
6. Complete statements that describe the major systems used in outboard engines.
7. State applications for the types of pistons commonly used in outboard engines.
8. List the types of valves commonly used in outboard engines.
9. List the cylinder arrangements commonly used in outboard engines.
10. List the valve arrangements commonly used in outboard engines.
11. Interpret outboard-engine labels. (Assignment Sheet 1)
12. Classify outboard-engine designs by their valve and cylinder arrangements. (Assignment Sheet 2)
13. Complete outboard-engine information forms. (Assignment Sheet 3)

Outboard-Engine Design and Identification
Unit 1

Information Sheet

1. Characteristics used to identify outboard engines

Note: Outboard engines resemble engines used in other power product equipment applications in a number of ways. The power-production portions of both types of engines are essentially the same, consisting of one or more pistons each in a cylinder with valves that open and close to control the flow of the fuel/air mixture and exhaust gases and a crankshaft to output power. The primary difference is that some of the support functions that are not normally part of the engine on most other types of power product equipment are integrated in the outboard engine. For example, a garden tractor may have a mechanical linkage such as a belt, chain, or shaft that transfers the engine output to the transmission and then through drive shafts to the drive wheels. These components of the drive train can be widely spread across the garden-tractor chassis. However, in a typical outboard engine, an extension to the crankshaft (the drive shaft) passes through the midsection of the engine to the gearcase and provides output to the propeller, which is equivalent to the drive wheel on the tractor. Thus, some of the characteristics used to identify other power product equipment engines are also used to identify outboard engines.

- **Manufacturer**

  Note: Student Supplement 1, "Outboard-Engine Manufacturers' Information," discusses outboard-engine manufacturers.

- **Horsepower**

  Note: Horsepower is the rated power output of an engine.

- **Combustion cycle**

  Note: Most outboard engines are two-stroke-cycle designs, though some four-stroke-cycle engines are also used (see Objectives 4 and 5).

- **Engine-support-system characteristics**

  Note: Engine-support systems are the systems that support engine operations (see the first section of Objective 6). Engines are classified by the characteristics of their support-system designs. For example, an engine cooling system may be either an air-cooled or water-cooled design. Most outboard-engine cooling systems are water cooled. The type of fuel system and the type of fuel used in that system are also important factors used in classifying engines.

- **Cylinder number**

  Note: Though some outboard engines have one cylinder, most have two or more cylinders. Three- and four-cylinder designs are sometimes used, and some engines use six or eight cylinders.

Information Sheet

- **Cylinder displacement**

  Note: Cylinder displacement, which is also called *engine displacement*, is the volume of all of an engine's cylinders. Cylinder displacement is normally stated in cubic inches, cubic centimeters, or liters.

- **Cylinder arrangement**

  Note: If an engine has more than one cylinder, the arrangement of cylinders is a design feature (see Objective 9). The more-common outboard-engine cylinder-arrangement design is two in-line cylinders. In-line cylinders are parallel to each other with the same orientation in the engine block. The other common type of cylinder arrangement is the V-type, which is used especially in larger engines.

- **Valve arrangement**

  Note: Valve arrangement (see Objective 10) involves both the relationship between the valves and the cylinders and the relationship of the valves to each other. For two-stroke-cycle engines, reed valves are normally used and their arrangement is a critical factor in the type of scavenging used. For four-stroke-cycle engines, the valves are typically overhead. They may be set at an angle to the cylinder.

2. **Major sections of outboard engines and their purposes** (see Figure 1 on the next page)

   Note: Outboard engines are constructed in three sections: (1) the power head, (2) the midsection, and (3) the lower unit. Each section serves the specific purpose listed below. Student Supplement 2, "Outboard-Engine Construction," provides a more-complete discussion of the major sections of outboard engines.

   - **Power head**—Houses the engine and produces the power to drive a boat

   - **Midsection**—Joins the power head to the lower unit and provides a means of mounting the engine to the boat

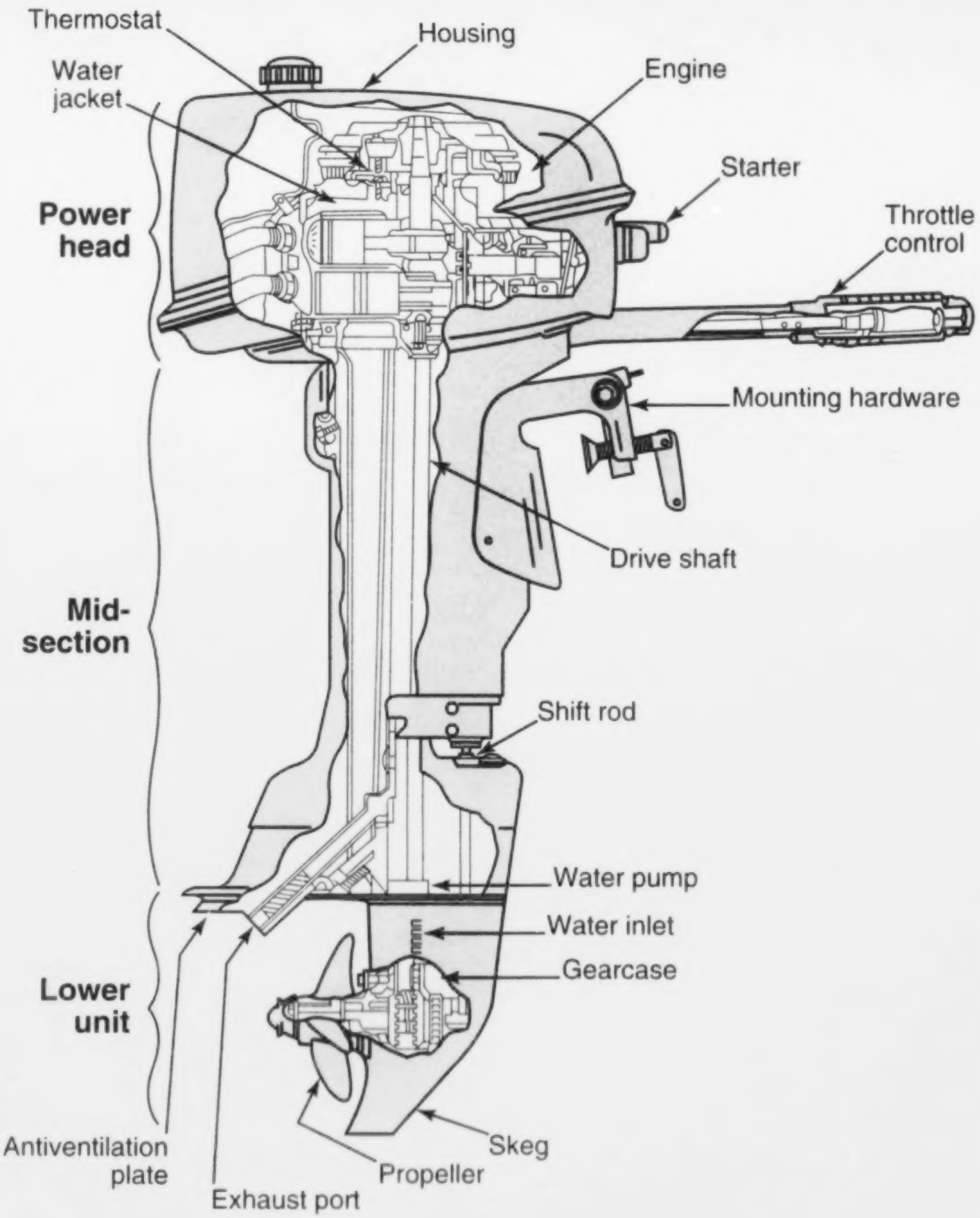
     Note: The midsection of the engine separates the power head—which must be protected from excess moisture—and the lower unit—which must be completely submerged in order to operate effectively. The midsection may also be referred to as the *engine leg*, the *motor leg*, or the *drive-shaft housing*. Some manufacturers treat the midsection and the lower unit as a single section; however, many manufacturers treat them as separate sections.

   - **Lower unit**—Converts the power output of an engine into a driving force in the propeller

     Note: Lower units are also referred to as *gearcases*.

Information Sheet

Figure 1: Major sections and major components of outboard engines


Thermostat
Housing
Water jacket
Engine
Starter
Power head
Throttle control
Mounting hardware
Drive shaft
Mid-section
Shift rod
Water pump
Water inlet
Gearcase
Lower unit
Skeg
Antiventilation plate
Propeller
Exhaust port

Information Sheet

3. **Major components of outboard engines and their functions** (see Figure 1 on the previous page)

Note: This objective discusses the major components typically found in outboard engines. The location of specific components can vary to some degree. The engine, gearcase, propeller, and some other components have fairly standard locations. However, design variations in systems such as the cooling system and fuel system can lead to different component placements. For example, the cooling system has an inlet low on the engine, routes water to the engine, and provides an exhaust near the propeller shaft, and the location of the water pump and thermostat within the cooling system can vary greatly (see Student Supplement 2).

- **Engine**—Produces the power to drive a boat
- **Throttle control**—Adjusts the fuel/air mixture to regulate engine speed
- **Starter**—Turns the engine flywheel to begin the internal-combustion process

  Note: Some engines have rope-rewind starters; others use electric starters. A few models are equipped with both types of starters.

- **Water jacket**—Allows the circulation of water around the engine to remove heat

  Note: The water jacket consists of cavities in the metal portions of the engine block and head that adjoin high-heat areas such as the combustion chamber. Water is pumped into the water jacket, forced over the heated surfaces, and then, is forced out the exhaust port to remove engine heat.

- **Thermostat**—Controls the direction of coolant flow based on engine temperature

  Note: The thermostat is simply a temperature-sensitive valve. In the open position, water flows past the valve; in the closed position, the valve stops the flow of water. The thermostat allows water to flow through the water jacket when the engine is hot, but it diverts water around the water jacket when the engine is cool.

- **Housing**—Protects the engine from the environment
- **Mounting hardware**—Allows the engine to be installed on a boat

  Note: Outboard engines are designed to mount on either a 15-inch or 20-inch boat transom. However, an engine designed to be mounted on a 15-inch transom comes with an extension kit that can be adjusted for installation on a 20-inch transom.

  The mounting hardware is generally an integrated unit consisting of the stern bracket that mounts to the boat transom, the swivel bracket that allows the engine to tilt up for transport, and the steering bracket that permits the engine to pivot laterally to control the direction of boat travel.

- **Drive shaft**—Transfers the rotary power from the engine to the gearcase
- **Shift rod**—Changes the gear relationships to allow forward or reverse movement of the boat

  Note: Some engines, especially low-horsepower models, offer only forward gear.

- **Water pump**—Picks up water and moves it through the cooling system

  Note: The water pump may be located in either the midsection or in the lower unit.

Information Sheet

- **Antiventilation plate**—Separates the submerged and above-water portions of the engine

  Note: The antiventilation plate is designed to ride just below the surface of the water at an angle approximately parallel to the lower planing surface of a boat. The primary purpose of the plate is to control the disturbance caused by the turning of the propeller. If the water stream produced by the propeller were allowed to spread too quickly, engine efficiency would be reduced. Also, if water were pulled from too near the surface, air would be captured in the flow and the efficiency of the propeller would be reduced. This condition is known as *cavitation*, which is why the component may also be referred to as an *anticavitation plate*.

- **Exhaust port**—Allows water from the cooling system and exhaust gases from the engine to exit the engine

- **Water inlet**—Provides an intake port for the cooling-system water

  Note: Water is moved by the water pump through a tube to the water jacket.

- **Gearcase**—Houses the gears that transmit power from the drive shaft to the propeller

  Note: Some outboard engines have a single gear ratio so that the torque output for any engine speed is essentially the same. Others have variable gears that can be changed for high- or low-speed operation.

- **Propeller**—Moves water from one side of its blades to the other to create the movement of the boat

  Note: Propellers are often neglected as a service item; however, for good engine efficiency and boat performance, the propeller must be properly matched to the boat and engine, be properly balanced and installed, and be free of damage and distortion.

- **Skeg**—Improves steering, helps provide more-even water flow past the propeller, and protects the propeller

4. **Description of the combustion cycle of two-stroke-cycle outboard engines** (see Figure 2 on the next page)

   Note: Two-stroke-cycle outboard engines operate like other two-stroke-cycle engines, using the action of the piston to intake the fuel/air mixture and to force the exhaust gases from the cylinder. The term *two stroke* refers to the fact that one combustion cycle consists of two strokes of the piston—one toward the spark plug and one away from the spark plug.

   a. **Intake/compression stroke**

      - **Intake event**—The piston completes its movement toward the crankcase, opening the transfer port and allowing the fuel/air mixture to enter the combustion chamber.

      - **Compression event**—The piston moves toward the combustion chamber, covering the transfer and exhaust ports and compressing the fuel/air mixture.

        Note: During the compression event, movement of the piston also creates a suction on the intake port, opening the intake port and allowing fresh fuel/air mixture to enter the crankcase. In two-stroke-cycle engines, the fuel/air mixture normally contains oil droplets also to improve lubrication.

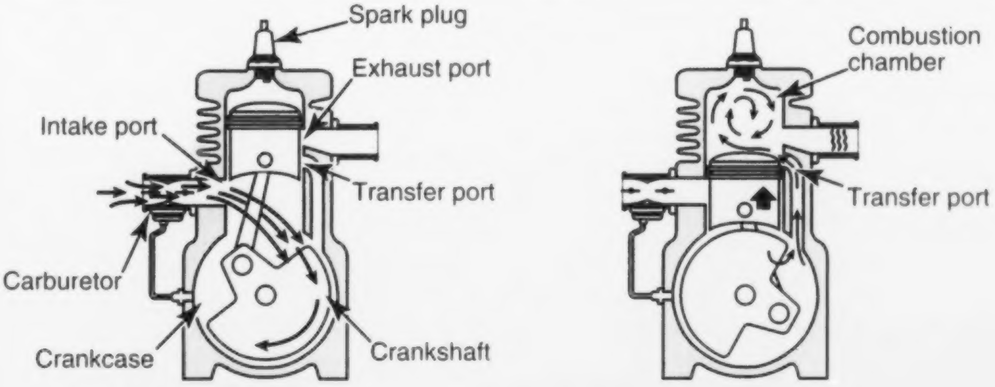
b. **Power/exhaust stroke**

- **Power event**—The piston completes its movement toward the combustion chamber, and the intake port closes, sealing the fuel/air mixture in the crankcase; simultaneously, a spark at the spark plug ignites the compressed fuel/air mixture.

  Note: As described here, ignition occurs during the power event. Some other sources may describe ignition as a separate event.

- **Exhaust event**—The piston is forced away from the combustion chamber, causing the crankshaft to turn; as the piston moves away from the combustion chamber, the exhaust port opens, allowing exhaust gases to escape from the combustion chamber; this also opens the transfer port for the beginning of the next intake event, and the entering fuel/air mixture helps to scavenge the exhaust gases.

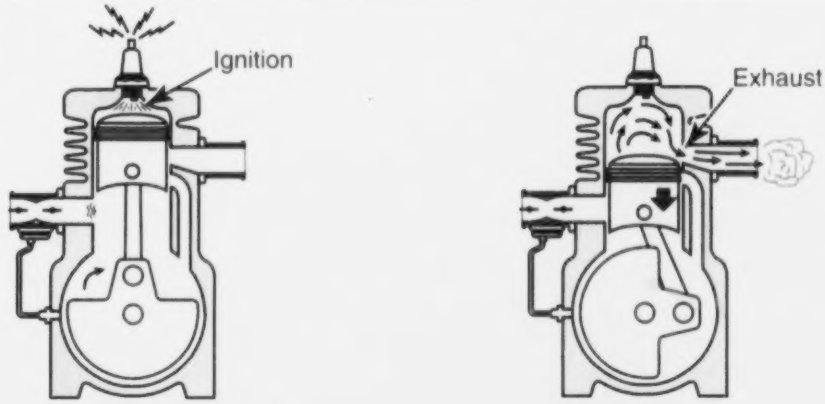
Figure 2: Combustion cycle of two-stroke-cycle outboard engines


Spark plug
Exhaust port
Intake port
Transfer port
Carburetor
Crankcase
Crankshaft
Combustion chamber
Transfer port

Intake event

Compression event

a. **Intake/compression stroke**


Ignition
Exhaust port

Power event

Exhaust event

b. **Power/exhaust stroke**

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Information Sheet

5. Description of the combustion cycle of four-stroke-cycle outboard engines (see Figure 3)

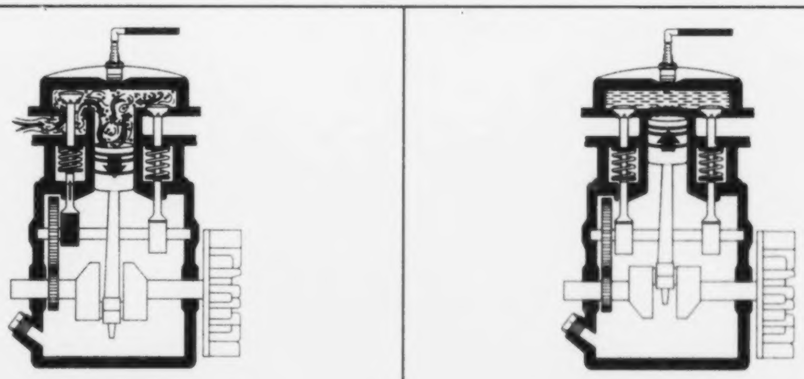
Note: The term *four stroke* refers to the fact that, in engines of this design, it takes four movements (strokes) of the piston to complete the combustion cycle described below. Every other movement of the piston away from the combustion chamber is a power stroke.

- **Intake stroke**—The piston moves away from the combustion chamber with the exhaust valve closed and the intake valve open, pulling fuel/air mixture into the combustion chamber.
- **Compression stroke**—The piston moves toward the combustion chamber with both valves closed, compressing the fuel/air mixture.
- **Power stroke**—With both valves closed, a spark at the spark plug ignites the compressed fuel/air mixture, forcing the piston away from the combustion chamber, which rotates the crankshaft.

  Note: As described here, ignition occurs during the power event. Some other sources may describe ignition as a separate event.

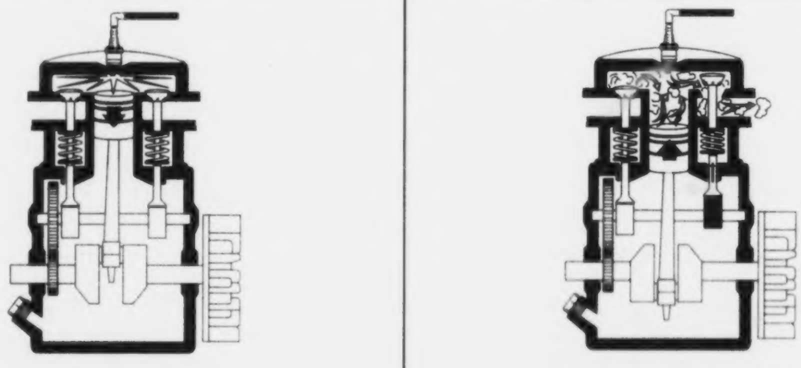
- **Exhaust stroke**—The piston moves toward the combustion chamber with the intake valve closed and the exhaust valve open, forcing exhaust gases from the combustion chamber.

Figure 3: Combustion cycle of four-stroke-cycle outboard engines



a. **Intake stroke**

b. **Compression stroke**



c. **Power stroke**

d. **Exhaust stroke**

Information Sheet

6. Major systems used in outboard engines and their descriptions

Note: There are four major systems used in outboard engines: (1) the engine-support systems, (2) the power-output system, (3) the control system, and (4) the safety system. All four are discussed in the sections below.

- **Engine-support systems**

  Note: Outboard-engine engine-support systems are similar in many ways to the engine systems used on other types of power product equipment, but they also have marked differences. Many of the systems common to other types of engines operate differently and have different components in outboard engines. Therefore, familiarity with the systems of other types of power product equipment engines does not necessarily mean that a technician understands the engine-support systems of outboard engines. The engine-support systems are introduced here, but will be discussed in detail in Unit 2, "Operation and Service of Engine-Support Systems."

  a. **Fuel system**

  — The fuel system mixes fuel with air and delivers it to the combustion chamber.

  — Most outboard engines use either a diaphragm fuel pump or a gravity feed assisted by the low-pressure suction created in the crankcase during the internal-combustion process.

  b. **Lubrication system**

  — Most outboard engines are two-stroke-cycle engines, which means that lubrication is achieved by mixing oil with the fuel.

  — Four-stroke-cycle engines use oil slingers or pump systems to circulate lubricant.

  — Some multiple-cylinder engines include a crankcase bleed system to return unburned oil to the cylinders, bearings, or other components to supplement the main lubrication system.

  c. **Cooling system**

  — The cooling system helps remove heat from the engine.

  — Most outboard engines are water cooled.

  — The cooling system includes a pump that pulls water into the engine and passes it over heated parts.

  — While some air cooling takes place, the cooling effect of this air is limited by the engine coverings that are designed to reduce the engine's exposure to water.

  d. **Ignition system**

  — The ignition system provides the spark that ignites the fuel/air mixture.

  — Because of the high humidity of the operating environment of outboard engines, ignition modules and spark plugs may have special characteristics when compared to those used in other types of power product equipment.

Information Sheet

e. **Starting system**

- — The starting system turns the flywheel to begin the internal-combustion cycle.
- — Some outboard engines have rope-rewind starters, many are equipped with electric starters, and some are equipped with both types of starters.
- — A battery is used to power electric starters.
- — The battery may also be used to power some electrical systems, such as running lights, especially when the engine is not running.

f. **Charging system**

- — The charging system produces electricity to maintain a level of electrical charge in the battery (recharge the battery) and to power select electrical circuits.

g. **Exhaust system**

- — The exhaust system removes unburned fuel and combustion gases from the engine.
- — Though some outboard engines include mufflers, most route the exhaust gases to exit the engine below the water level.
- — Most outboard engines also mix water from the cooling system with exhaust gases to provide additional cooling.

- **Power-output system**

Note: The power-output system will be discussed in detail in Unit 3, "Operation and Service of Power-Output Systems."

a. The components of the power-output system transmit the power from the engine to a point where work is done.

b. Unlike most types of power product equipment, the power-output system is integrated in outboard engines.

c. The power-output system in an outboard engine consists of an extension to the crankshaft, which serves as the drive shaft and passes through the midsection to mesh with the gearcase. The gears drive the propeller shaft, which in turn powers the propeller.

d. The propeller is the point where work is done; it provides the thrust that drives the boat, much like the drive wheels on self-powered equipment.

- **Control system**

Note: The control system will be discussed in detail in Unit 4, "Operation and Service of Control and Safety Systems."

a. The control system allows the operator to adjust different aspects of the engine's operation or position, such as engine speed, the direction of propeller rotation, the gearcase setting, tilt, trim, and other performance features.

Information Sheet

b. Control-system devices are generally located in one of two places on boats with outboard engines: (1) on the tiller or (2) remote controls.

c. The most-common type of control, especially on smaller engines, is called a *tiller.* A tiller is simply a handle that protrudes from the engine and allows the boat operator to pivot the engine horizontally. Tiller handles also usually allow the operator to tilt the engine vertically. Some tiller handles include controls for throttle settings, operating an electric starter, tilt and trim, or other functions.

d. Controls located at places other than the tiller are referred to as *remote controls* and include steering systems, throttle handles, gearcase shift levers, starter switches, power tilt-and-trim controls, and other functional controls.

- **Safety system**

  Note: The safety system will also be discussed in greater detail in Unit 4, "Operation and Service of Control and Safety Systems."

  a. The safety-system devices prevent the operation of the engine or boat system during conditions when such operation might result in equipment damage or injury.

  b. In outboard engines, safety-system devices may be installed on the engine itself, in some engine-support system, or in the control system.

  c. Common safety devices include tilt switches that cut off the flow of fuel if the boat is at a dangerous angle, neutral safety switches that will not allow the engine to start if the gears are engaged, emergency-stop lanyards that stop the engine if the operator of the boat is too far from the control area, revolution limiters to prevent engine overspeed, and others.

7. Types of pistons commonly used in outboard engines and their applications

Note: Outboard engines may be either two- or four-stroke-cycle engines. The type of engine and other factors will affect the kind of pistons, valves, and other components that are used.

- **Flat-head pistons** (see Figure 4-a on the next page)—Commonly used in four-stroke-cycle engines

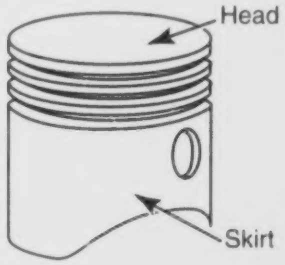
  Note: Although referred to as *flat-head pistons*, not all four-stroke-cycle engines use pistons that are completely flat across the top, as shown in Figure 4-a on the next page. Some pistons have slight domes or other shape variations for specific applications, such as racing engines.

- **Deflector-head pistons** (see Figure 4-b on the next page)—Commonly used in two-stroke-cycle engines in which they serve to improve compression and exhaust removal, but are also found in four-stroke-cycle engines

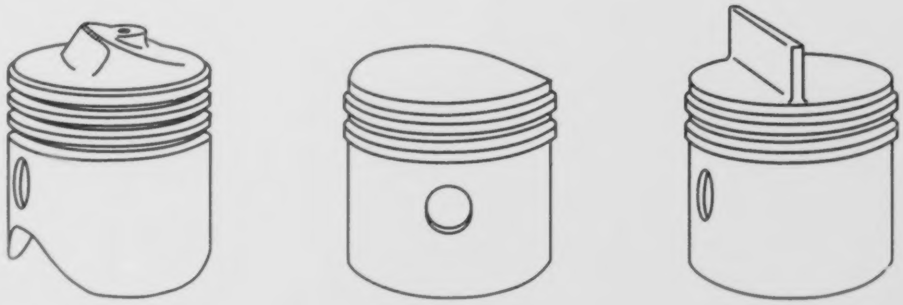
  Note: Numerous piston-head designs are available to provide the deflection action (see Figure 4-b on the next page).

Information Sheet

Figure 4: Piston-head designs



a. **Flat-head piston** (standard piston)



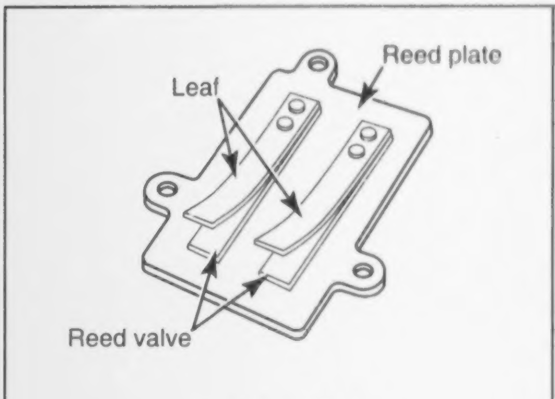
b. **Deflector-head pistons**

8. Types of valves commonly used in outboard engines

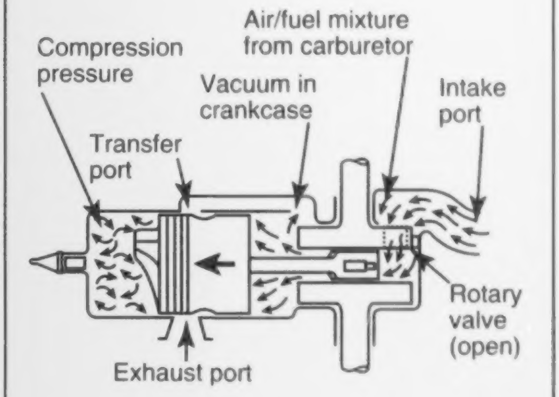
Note: Outboard engines may use any of the types of valves commonly used in two- or four-stroke-cycle engines. Because most outboard engines are two-stroke-cycle designs, reed valves are perhaps the most-commonly-used type of valve. Reed valves may be of an external or internal design. For example, a reed valve may be placed in the crankcase so that it opens internally to allow the fuel mixture to enter. On the other hand, a reed valve may be installed in the exhaust port external to the combustion chamber and open externally.

- **Reed valve** (see Figure 5-a on the next page)
- **Rotary valve** (see Figure 5-b on the next page)
- **Stem valve** (see Figure 5-c on the next page)

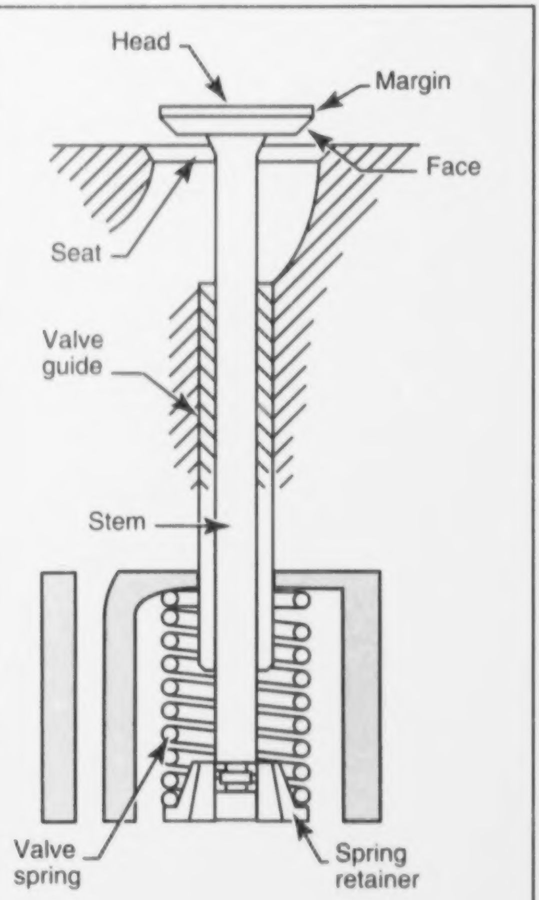
Figure 5: Types of valves


Reed plate
Leaf
Reed valve

a. **Reed valve**


Air/fuel mixture from carburetor
Compression pressure
Vacuum in crankcase
Intake port
Transfer port
Rotary valve (open)
Exhaust port

b. **Rotary valve**


Head
Margin
Face
Seat
Valve guide
Stem
Valve spring
Spring retainer

c. **Stem valve**

9. **Cylinder arrangements commonly used in outboard engines**

Note: The more-common outboard-engine cylinder-arrangement design is two in-line cylinders. In-line cylinders are parallel to each other with the same orientation in the engine block. Another common type of cylinder arrangement is a V with the cylinders set at an angle to each other.

- **In-line cylinder arrangement** (see Figure 6 on the next page)
- **V-type cylinder arrangement** (see Figure 7 on the next page)

Information Sheet

Figure 6: In-line cylinder arrangement

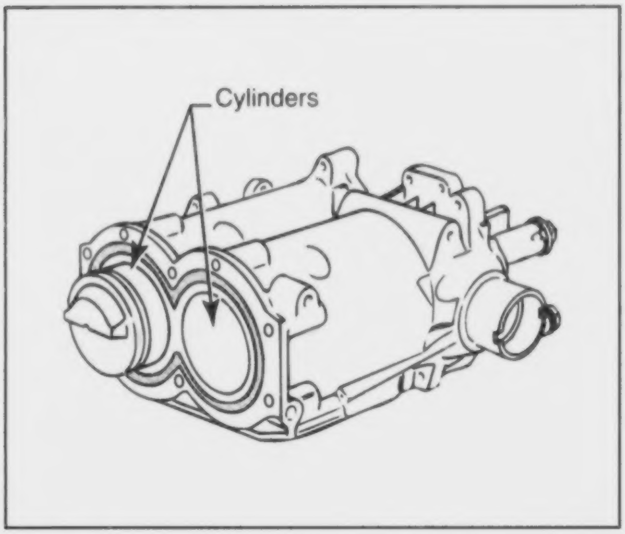
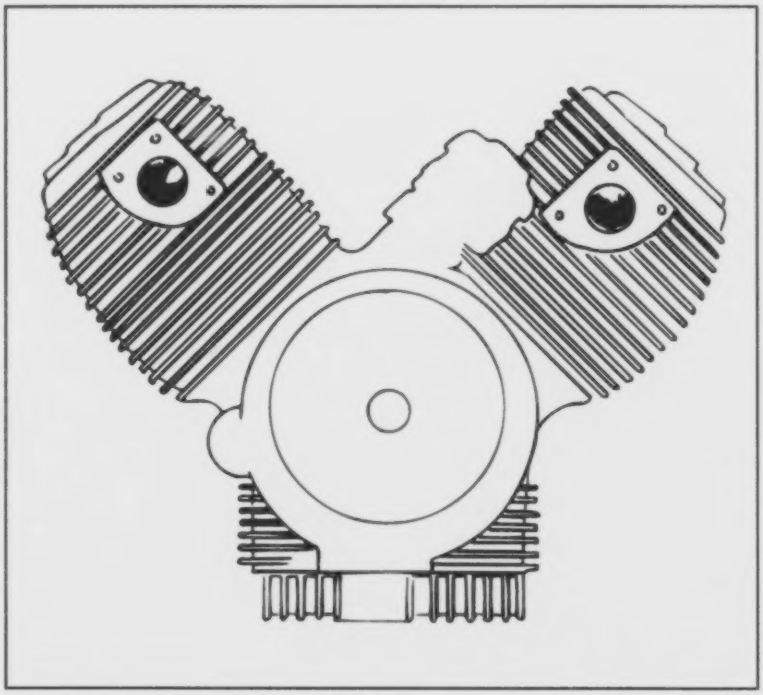


Figure 6 reprinted with permission of McGraw-Hill Publishing Company. *Mechanics of Small Engines* by Henry F. Atkinson, copyright 1990.

Figure 7: V-type cylinder arrangement



10. Valve arrangements commonly used in outboard engines

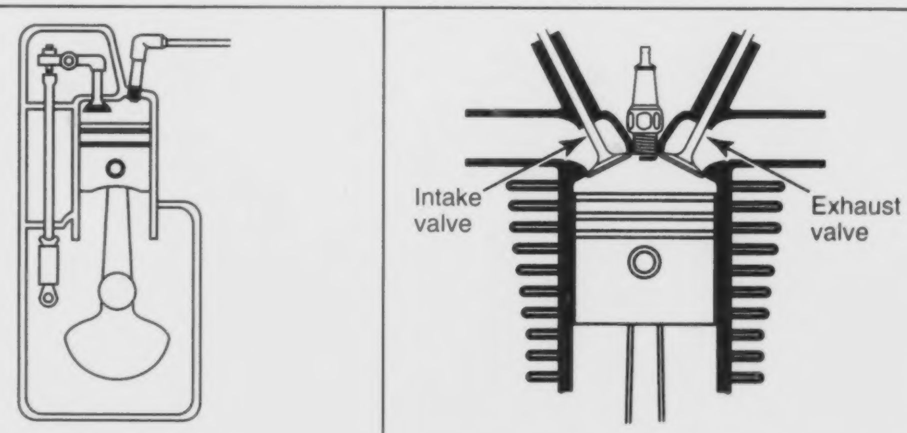
Note: The arrangement of the valves and the cylinders in an outboard engine will depend on a number of factors. Most significantly are whether the engine is a two- or four-stroke-cycle design and how many cylinders are used. Other factors include the types of valves used, purpose of the engine (power versus fuel economy, for example), manufacturer preferences, and additional systems used to support engine operation.

Outboard engines generally use one of four valve designs. Virtually all four-stroke-cycle engines use stem valves, such as those shown in Figure 8. Two-stroke-cycle engines may use reed valves, rotary valves, or simple ports that are covered or exposed by the movement of the piston. Examples of these are shown in Figures 9 and 10 on page 17.

- **I-head arrangement** (see Figure 8-a)
- **Valves set at an angle to each other** (see Figure 8-b)

  Note: The I-head arrangement and those that set the valves at an angle to each other are referred to as *overhead-valve designs* because the valves are often above the combustion chamber—that is, opposite the cylinder from the crankcase. In many outboard engines, the cylinders are placed horizontally so that "overhead" valves actually lie in the same horizontal plane as that along which the piston travels.

Figure 8: Overhead-valve arrangements



a. **I-head arrangement**

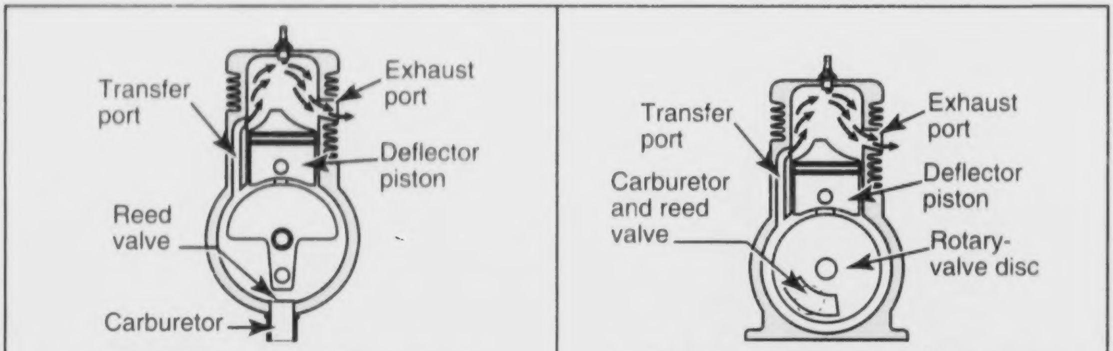
b. **Valves set at an angle to each other**

Information Sheet

- **Cross-scavenged** (see Figure 9)

  Note: The term *scavenging* refers to the process of removing exhaust gases from the combustion chamber of a two-stroke-cycle engine. Scavenging is controlled by the arrangement of the valves, the number of valves, and the timing of when they open and close. In a cross-scavenged design, the intake and exhaust ports are more or less directly opposite each other. The piston head will be a deflector-type in order to separate intake and exhaust gases. The intake event is generally controlled by either a reed valve or a rotary valve.

Figure 9: Cross-scavenged designs


Transfer port
Exhaust port
Deflector piston
Reed valve
Carburetor
Transfer port
Exhaust port
Carburetor and reed valve
Deflector piston
Rotary-valve disc

a. **Cross-scavenged with reed valve**

b. **Cross-scavenged with rotary valve**

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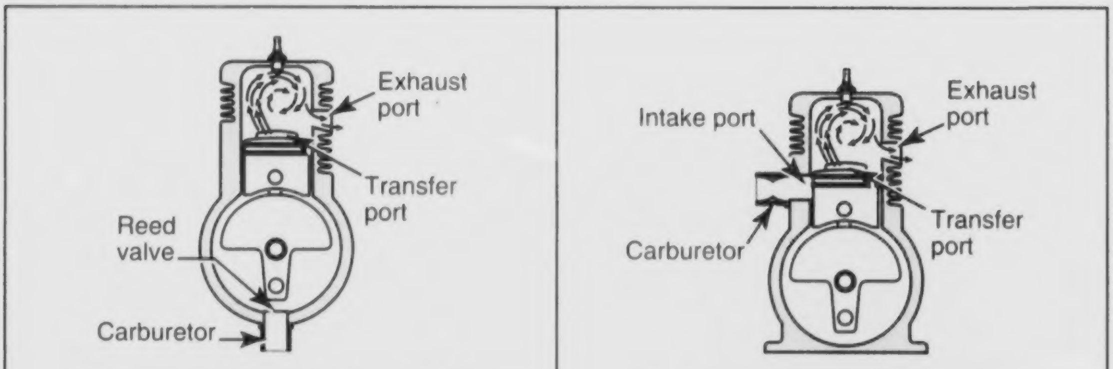
- **Loop-scavenged** (see Figure 10)

  Note: In loop-scavenged designs, the intake and exhaust ports are offset from one another in the cylinder walls. This arrangement causes the combustion-chamber gases to swirl. To improve the swirling or looping effect, many engines of this design will have a second intake port. The intake event is usually controlled by a reed valve or by the position of the piston in relation to the intake port.

Figure 10: Loop-scavenged designs


Exhaust port
Transfer port
Reed valve
Carburetor
Intake port
Exhaust port
Carburetor
Transfer port

a. **Loop-scavenged with reed valve**

b. **Loop-scavenged with piston-controlled third port**

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Outboard-Engine Design and Identification
Unit 1

Student Supplement 1—Outboard-Engine Manufacturers' Information

Introduction

Outboard engines are a very specialized type of power product equipment, and they must be designed to work in conjunction with the boat on which they are used. For that reason, many power product equipment engine manufacturers do not produce outboard engines, and some companies that do not build engines for lawn and garden equipment or construction equipment do manufacture outboard engines. Consequently, technicians who are familiar with other types of power product equipment will encounter manufacturers whose names and products they may not recognize as they are dealing with outboard engines.

Additionally, these specialized outboard-engine manufacturers build engines for a number of resellers, such as large department-store chains and catalog outlets. Therefore, the engines of one outboard-engine manufacturer may be marketed under a number of different brand names.

Finally, the restrictions of the environment in which outboard engines operate limit design options in many ways, meaning that the outboard engines from various manufacturers have a lot of features in common with each other.

All of these factors mean that outboard engines have many similarities—including common vocabulary, specifications, design features, etc.—but they also have many differences. This supplement will introduce you to the major outboard-engine manufacturers and their products.

Manufacturers

The United States (with some supplemental production in Canada and Mexico) and Japan are the major countries of origin for outboard engines. The following lists the major manufacturers in alphabetical order and describes their typical products. A number of the companies listed below have consolidated or have produced engines with other brand names. They are listed here because technicians will encounter engines that are several years old. A good technician learns the relationships among the engines and companies in order to recognize engine designs, service requirements, and sources of service data.

British Seagull Company, Limited. Sold as Seagull or British Seagull. Produces 64- and 102-cubic-centimeter-displacement engines.

Clinton Engines Corporation. Sold as Clinton, Chief, and some Sears engines. Produces single-cylinder engines that range from 4.48- to 10.14-cubic-inch displacement.

The Eska Company. Sold as Sears, Explorer, Federal, Golden Jet, Hanimex, Hiawatha, Pathfinder, Seaco, Seacruiser-Grant, Sea Hawk, Skipper, Sportfisher, and Wizard. Produces single-cylinder engines from 3 to 7.5 horsepower. Produces double-cylinder engines from 9.5 to 15 horsepower.

HMC. Sold as Cruise 'N Carry. Produces single-cylinder engines in sizes of 1.4, 1.5, and 2.7 horsepower.

Mariner International Company. Sold as Mariner. Produces engines from 2 to 200 horsepower in one-, two-, three-, four-, and six-cylinder configurations.

Mercury-Marine Corporation. Sold as Mercury and Merc. Produces 2.2- to 300-horsepower engines in one-, two-, three-, four-, and six-cylinder configurations.

Montgomery Ward. Sold up until 1980 as Sea King. Includes some engines manufactured by Clinton. Produced 6- and 9.2-horsepower engines.

Outboard Marine Corporation (OMC)**.** Sold as Evinrude and Johnson. Each engine size is sold under both names. Engines range in size from 1.5 to 300 horsepower in one-, two-, three-, four-, six-, and eight-cylinder configurations.

Suzuki America Corporation. Sold as Suzuki. Range in size from 2 to 200 horsepower in one-, two-, three-, four-, and six-cylinder configurations.

Tanaka Kogyo U.S.A. Sold as Tanaka or TOB. Range in size from 1.2 to 5.5 horsepower in single-cylinder configurations.

Tohatsu U.S.A. Sold as Tohatsu. Range in size from 2.5 to 70 horsepower in one- and two-cylinder configurations.

U.S. Marine Corporation. Sold as Chrysler and Force. Chrysler engines range from 3.5 to 150 horsepower in one-, two-, three-, and four-cylinder configurations. Force engines range from 4 to 50 horsepower in one- and two-cylinder designs.

Yamaha Motor Corporation U.S.A. Sold as Yamaha. Range in size from 2 to 225 horsepower in one- and multiple-cylinder configurations.

Engine-support-system components

Many of the components used in outboard engines are not produced by the engine manufacturer. In some cases, other power product equipment manufacturers may be involved, such as Tecumseh producing power heads for Eska engines. Fuel pumps, carburetors, spark plugs, piston rings, reed valves, and other parts are likely to be built by companies that specialize in particular types of components. This can have a significant impact on service procedures. For example, Chrysler 20-horsepower engines use Tillotson MD and WD carburetors. Sea King 9.9-horsepower engines used Tillotson carburetors until 1971 and Walbro carburetors after 1971. A technician must be able to recognize such differences and to select the correct specifications based on the specific configuration of an engine. These differences may be based on model years or on serial numbers.

Engine labels

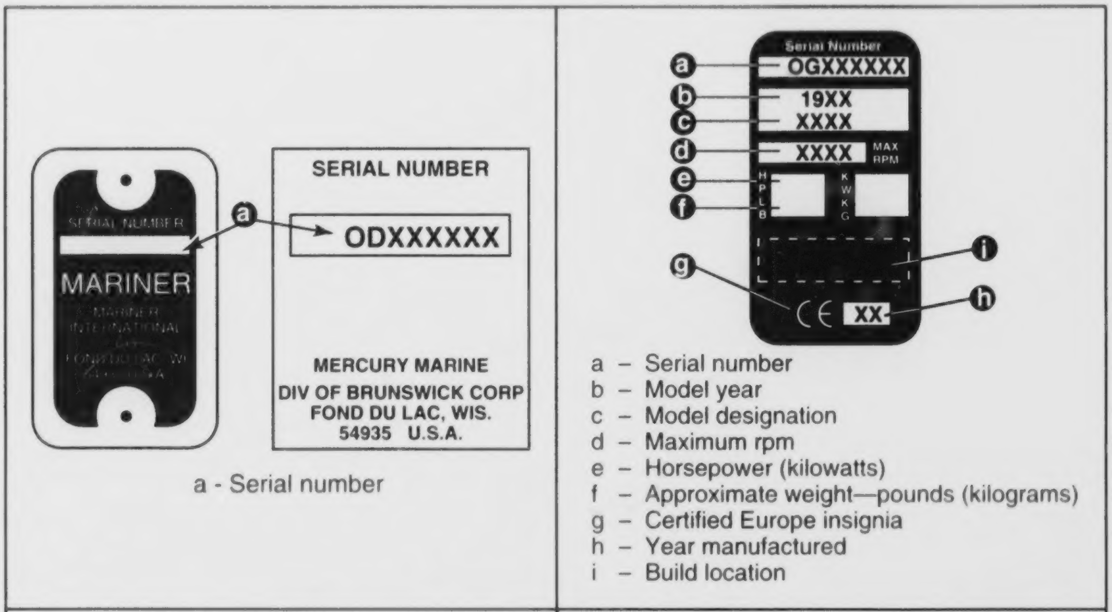
Outboard-engine manufacturers use labels to provide technicians, customers, and distributors with information about the engine. The exact information, how it is presented, and other details will vary from one manufacturer to another, but most engine labels contain basically the same type of information. The following paragraphs describe information about engine labels used by Mercury Marine, including Mercury and Mariner outboards. Other manufacturers follow similar practices and generally describe their labeling practices in service manuals or technical bulletins.

Student Supplement 1

- Early Mercury-Marine engines usually have a single label such as that shown in Figure 1-a below. The label identifies the manufacturer and in some cases the engine model number. The label also carries a serial number. Early Mercury-Mariner serial numbers were simply seven-digit numbers given in the sequence of manufacture. Later serial numbers contain letter prefixes (the first one or two characters in the serial number).

- Beginning in 1995, Mercury Marine expanded the information provided on their labels. These labels (see Figure 1-b) include the serial number, model year, model designation, maximum rpm, power rating in horsepower and kilowatts, approximate weight in pounds and kilograms, the location of manufacture, and the year of manufacture.

Figure 1: Mercury-Marine serial-number sequence


SERIAL NUMBER
MARINER
a
SERIAL NUMBER
ODXXXXXX
MERCURY MARINE
DIV OF BRUNSWICK CORP
FOND DU LAC, WIS.
54935 U.S.A.
a - Serial number
Serial Number
a
OGXXXXXX
b
19XX
c
XXXX
d
XXXX
MAX RPM
e
HP
f
LB
KW
KG
i
g
h
XX
a – Serial number
b – Model year
c – Model designation
d – Maximum rpm
e – Horsepower (kilowatts)
f – Approximate weight—pounds (kilograms)
g – Certified Europe insignia
h – Year manufactured
i – Build location

a. **Early Mercury-Marine engine labels**

b. **Expanded-information Mercury-Marine engine labels—beginning in 1995**

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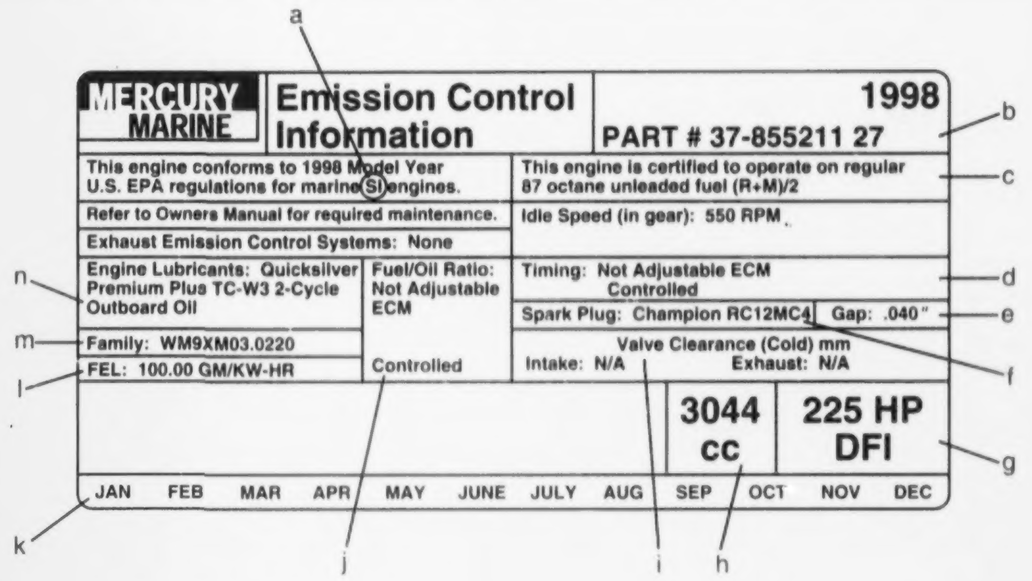
- Beginning in 1998, the federal government began requiring all outboard engines to be labeled with information related to exhaust emissions. So, current labels contain information about fuel, lubricants, spark plugs, carburetor adjustments, and other information. Most of this information is self-explanatory, as is shown in Figure 2 on the next page.

- Currently, Mercury-Marine labels also contain coded family information. Figure 2 shows an example of that label interpretation.

Student Supplement 1

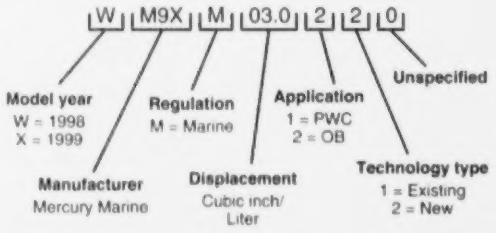
Figure 2: Current certification label and family information


a
b
c
d
e
f
g
h
i
j
k
l
m
n

MERCURY MARINE
Emission Control Information
1998
PART # 37-855211 27
This engine conforms to 1998 Model Year U.S. EPA regulations for marine SI engines.
This engine is certified to operate on regular 87 octane unleaded fuel (R+M)/2
Refer to Owners Manual for required maintenance.
Idle Speed (in gear): 550 RPM
Exhaust Emission Control Systems: None
Engine Lubricants: Quicksilver Premium Plus TC-W3 2-Cycle Outboard Oil
Fuel/Oil Ratio: Not Adjustable ECM Controlled
Timing: Not Adjustable ECM Controlled
Spark Plug: Champion RC12MC4
Gap: .040"
Family: WM9XM03.0220
FEL: 100.00 GM/KW-HR
Valve Clearance (Cold) mm
Intake: N/A
Exhaust: N/A
3044 cc
225 HP DFI
JAN FEB MAR APR MAY JUNE JULY AUG SEP OCT NOV DEC

a – Spark ignition (SI)
b – Model year of engine, and production-decal part number
c – Type and octane of fuel engine is designed to operate on
d – Timing specifications when adjustable
e – Spark-plug gap, in inches
f – Recommended spark plug, only this plug or equivalent should be used
g – Engine-horsepower rating
h – Displacement (cc = cubic centimeter)
i – Valve clearance (four-stroke engines only)
j – Recommended oil/fuel ratio for best engine performance
k – Month of production (boxing month will be punched)
l – FEL: Represents (Mercury Marine) statement of the maximum emissions output for the engine family.

m – Family example:


W
M9X
M
03.0
2
2
0
Unspecified
Model year
W = 1998
X = 1999
Regulation
M = Marine
Application
1 = PWC
2 = OB
Manufacturer
Mercury Marine
Displacement
Cubic inch/Liter
Technology type
1 = Existing
2 = New

n – Engine lubricants recommended by the manufacturer

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Outboard-Engine Design and Identification
Unit 1

Student Supplement 2—Outboard-Engine Construction

Introduction

Engine designs vary from manufacturer to manufacturer and from model to model. Therefore, the construction and functioning of any engine section is not the same for all engines. This is particularly true of the midsection and the lower unit. While the power head usually houses the combustion chamber and the components necessary to support the combustion process, midsection and lower-unit functions may vary. Generally, the midsection will allow the transfer of power from the power head to the lower unit and provide protection to the parts that perform that function. The midsection may also allow the transfer of cooling water from the lake or stream in which the boat travels to the engine and the transfer of heated water from the engine and back to the body of water.

The lower unit converts the power of the engine into thrusting force to propel the boat forward or, in some engines, allows the direction of travel to be reversed. The lower unit is also designed to provide improved stability of the engine as the boat travels through the water and improved steering.

In accomplishing these general tasks, the exact placement of components may vary. For example, a water pump may be placed in the lower unit, midsection, or even the power head. However, regardless of the precise location of a component, the functions and operation of engine sections are basically as described in this supplement.

Power-head construction

The power head will house one or more cylinders, each with a piston that compresses cylinder volume to concentrate the fuel mixture and form a combustion chamber with the head. Other vital components of the combustion-chamber design include the valves or ports that open to allow the fuel mixture to enter the combustion chamber and exhaust gases to exit. Outboard-engine valves and ports use a number of designs as explained in the information sheet.

The force necessary to cause the valves and pistons to move is applied by rotating shafts. The crankshaft drives the pistons, while a camshaft is used to open and close stem valves.

Other functions required to support the combustion process are the delivery of the fuel/air mixture to the combustion chamber and the creation of a spark to ignite the compressed fuel/air mixture. Many of the components of both the fuel and ignition systems are attached to the power head. Generally, the proper mixture of air and fuel is created through the use of a carburetor or fuel injectors. Most outboard engines use a fuel pump to move fuel from the fuel tank to the carburetor or injectors.

Some engines have fuel tanks attached to the power head, though many have separate "external" fuel tanks. The fuel pump may be mounted on the power head or at virtually any point between the fuel tank and the power head. The power head may also house an air inlet, which often contains a separator box.

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The ignition-system components integrated into the power head include the spark plug and the electrical circuitry (switches, coils, condensers, etc.) required to generate and control spark production. This also includes the flywheel, for it is the rotation of the flywheel attached to the crankshaft that electromagnetically induces electrical current. Part of this electrical output is used to keep the battery charged.

One purpose of the battery is to power the starter motor in order to initiate the combustion process. The starter has a gear that engages teeth on the flywheel to turn the crankshaft. The starter is generally attached to the power head, though the battery is usually separate from the engine and electrically connected by cables.

Other components that may be integrated into the power head include the water jacket to cool the engine, thermostat, oil injector, sensors, control linkages, tiller controls, and other parts, depending on engine design and operation.

Midsection construction

The housing of the midsection provides a rigid structure to join the power head and lower unit. The housing is usually narrow with a streamlined profile to reduce drag. Yet the housing must be strong enough to protect the internal components and to secure the other two sections to each other. The housing is normally joined to the power head and lower unit by conventional screws or bolts. The midsection housing is made to a particular length so that the propeller will be correctly positioned in the water for a boat transom of a standard height.

Internally, the housing is hollow or has one or more cavities passing through it. The cavities are designed to reduce the weight of the housing while increasing its strength. These openings allow water to be transferred back and forth between the lower unit and power head in water-cooled engines. The cavities also enclose moving parts such as the drive shaft and shift rod. The drive shaft connects to the crankshaft. Thus, the rotation of the crankshaft creates rotary motion in the drive shaft. The opposite end of the drive shaft is attached to a drive gear in the lower unit. In this way, power can be transferred through the gearcase to the propeller.

The shift rod is connected to the shift linkage, which may be a remote device near the boat steering wheel or a device on the engine-control handle that is operated directly by the driver of the boat. The other end of the shift rod is connected to a collar, fork, or other component in the lower unit. In this way, moving the shift linkage causes the shift rod to change position to place the gearcase in forward, reverse, or neutral. Some engines have only forward and neutral positions.

For water-cooled engines, the midsection will contain a water tube to transport water from the lower-unit intake port to the water jacket of the power head. Water is lifted through the water tube by a water pump. The water pump may be located in any of the three sections of the engine, depending on the power source for the pump. For example, the water pump may be an impeller in the lower unit driven by the propeller shaft. The water pump can be located in the power head with power provided by the crankshaft. In other designs, the water pump may be driven by the drive shaft and located in the midsection or lower unit. A thermostat is generally located at the point where the water tube connects to the water jacket, but

Student Supplement 2

it too may be found in various locations between the water intake and the water jacket.

A second passage in the midsection is called the *exhaust tube*. It is used to carry exhaust gases away from the power head. These gases are carried to the lower unit where they are normally expelled into the water stream of the propeller. This approach reduces noise and air pollution, eliminating the need for a muffler. Many engines also use the exhaust tube to return heated water from the water jacket into the body of water through which the boat is traveling.

The stern bracket allows the engine to be mounted to the transom of the boat. Stern brackets come in various designs and must often be selected to match an engine to a particular boat.

The swivel bracket allows the power head to be tilted forward, which in turn raises the lower unit. It may be necessary to raise the lower unit in order to operate in shallow water or among obstacles, to load or unload the boat, or to transport it on a trailer.

Finally, the midsection will contain a steering bracket that permits movement of the engine to the left or right. Thus, the force of the propeller can be directed to one side or the other to cause the boat to turn. The engine pivots around a kingpin or pilot shaft that passes through the steering bracket. The engine may be pivoted directly by the operator or through a remote steering system that is generally mechanical or hydraulic.

Lower-unit construction

The lower unit consists of the propeller and gearcase and a housing to protect the gearcase. The housing is designed to help stabilize the boat. For example, the connection between the lower unit and midsection is often flared into an antiventilation plate. This plate serves two primary purposes. First, it reduces the amount of air that will be captured by a propeller turning too close to the surface of the water. Second, it prevents the water that is displaced by the propeller from spreading too quickly. Either of these conditions would lead to a reduction in the efficiency of the propeller.

The skeg is a vertically flared piece normally located below and in front of the propeller. The skeg improves steering by increasing the surface area of the engine as it pivots like a rudder. The skeg also increases the speed of the water that reaches the propeller to improve thrust. The skeg can also deflect obstacles to protect the propeller from damage.

The lower-unit housing also provides openings for water intake and exhaust. Often, the water-intake port contains a screen or filter. As noted above, the lower unit may also contain the water pump or other components.

The major assembly in the lower unit is the gearcase. The gearcase receives the output of the drive shaft and transfers it to the propeller shaft. This generally involves changing the direction of the engine output from vertical to horizontal and often entails changing the amount of force and the flow of power, such as forward, reverse, or neutral.

The final component of the lower unit is the propeller. The propeller is discussed in detail in Unit 3, "Operation and Service of Power-Output Systems."

Outboard-Engine Design and Identification
Unit 1

Assignment Sheet 1—Interpret Outboard-Engine Labels

Name ______________________________ Date ______________

Evaluation criteria **Rating**

Directions have been followed. ______

Minimum of 85 percent of answers are correct. ______

Overall rating ______

Evaluator's comments ______________________________

Introduction Outboard-engine manufacturers assign model numbers, serial numbers, identification numbers, and other identifying labels that serve to define the characteristics of each outboard engine so that correct service procedures, parts, and specifications can be used on a particular engine. Over the production life of an engine model, specifications and parts are often improved. Service procedures are updated to show these changes and frequently indicate a modification by referring to serial numbers, date of manufacture, or other data that can be interpreted from the identification information. In this assignment sheet, you will practice interpreting engine-identification information for engines that you are likely to service in your career as a power product equipment technician.

Exercise

Directions Read Student Supplement 1, "Outboard-Engine Manufacturers' Information," and then, your instructor will assign you five engines to identify. Use what you know about engine design and the information provided by the engine manufacturers through reference materials and identification labels to provide the engine-identification information requested on the next page for the five engines. Write your answers on the blanks provided.

Assignment Sheet 1

1. **Engine 1**
   a. Manufacturer — ____________________
   b. Serial number — ____________________
   c. Horsepower — ____________________
   d. Displacement — ____________________
   e. Date of manufacture — ____________________

2. **Engine 2**
   a. Manufacturer — ____________________
   b. Serial number — ____________________
   c. Horsepower — ____________________
   d. Displacement — ____________________
   e. Date of manufacture — ____________________

3. **Engine 3**
   a. Manufacturer — ____________________
   b. Serial number — ____________________
   c. Horsepower — ____________________
   d. Displacement — ____________________
   e. Date of manufacture — ____________________

4. **Engine 4**
   a. Manufacturer — ____________________
   b. Serial number — ____________________
   c. Horsepower — ____________________
   d. Displacement — ____________________
   e. Date of manufacture — ____________________

5. **Engine 5**
   a. Manufacturer — ____________________
   b. Serial number — ____________________
   c. Horsepower — ____________________
   d. Displacement — ____________________
   e. Date of manufacture — ____________________

Outboard-Engine Design and Identification
Unit 1

Assignment Sheet 2—Classify Outboard-Engine Designs by Their Valve and Cylinder Arrangements

Name ______________________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	______
Minimum of 85 percent of answers are correct.	______
Overall rating	______

Evaluator's comments ______________________________

____

____

Introduction

Three of the characteristics used to classify outboard engines are (1) the number of cylinders the engine has, (2) the arrangement of those cylinders, and (3) the arrangement of the valves. These design features influence other characteristics such as horsepower and the design of engine-support systems, such as cooling and exhaust systems.

Naturally, it is important that a technician be able to recognize an engine so that he or she can correlate service requirements and specifications to the engine. In past studies, you learned to apply identification principles to engines more traditionally used for other types of power product equipment. This course concentrates on outboard engines, and this assignment sheet provides you with practice in applying similar principles to outboard engines.

Cylinder arrangement

Outboard engines may use any of the cylinder designs employed in other types of power product equipment engines; however, the common cylinder arrangements used for outboard engines are in-line and V. See the artwork in Objective 9 of the information sheet. However, while the various types of land-based power product equipment use either a horizontal- or vertical-crankshaft orientation, outboard engines are almost exclusively vertical-crankshaft designs. Thus, in-line cylinders and those in each bank of V-design multiple cylinders are generally stacked one above another.

Assignment Sheet 2

Exercise

Part A

Directions Find examples of outboard engines that use each of the cylinder arrangements listed below. Write the manufacturer's name and the engine-model number in the spaces provided below.

1. **In-line engine**
   a. Manufacturer's name — ______________________________
   b. Engine-model number — ______________________________
2. **V-type engine**
   a. Manufacturer's name — ______________________________
   b. Engine-model number — ______________________________

Valve arrangement The engine-design characteristic that most influences the type of valves used in an outboard engine is whether the engine is a two-stroke-cycle or four-stroke-cycle design.

Four-stroke-cycle designs

Four-stroke-cycle engines generally use stem valves. Outboard engines usually have overhead valves—that is, valves in the head. Overhead valves are usually arranged at an angle to each other (V or angle) or parallel to the stroke of the piston (I-head or straight). See the artwork in Objective 8 and Objective 10 of the information sheet.

Two-stroke-cycle designs

For two-stroke-cycle engines, one of three types of valve designs may be used: (1) the valve may be a reed valve, (2) a rotary valve, or (3) simply a port that is covered or revealed by the piston as the piston moves within the cylinder. Many engines will use more than one type of valve, such as a rotary or reed valve for the intake port and a piston-controlled port for the exhaust. The arrangements of the valves are designed to support a scavenging method (cross-scavenging or loop-scavenging). See the artwork in Objective 8 and Objective 10 in the information sheet.

Assignment Sheet 2

Exercise

Part B

Directions Find examples of engines that use each of the valve arrangements listed below. Write the manufacturer's name and the engine-model number in the spaces provided below.

1. **I-head**
   a. Manufacturer's name — ______________________________
   b. Engine-model number — ______________________________
2. **Valves set at an angle**
   a. Manufacturer's name — ______________________________
   b. Engine-model number — ______________________________
3. **Cross-scavenged**
   a. Manufacturer's name — ______________________________
   b. Engine-model number — ______________________________
4. **Loop-scavenged**
   a. Manufacturer's name — ______________________________
   b. Engine-model number — ______________________________

Outboard-Engine Design and Identification
Unit 1

Assignment Sheet 3—Complete Outboard-Engine Information Forms

Name ______________________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	_______
Minimum of 85 percent of answers are correct.	_______
Overall rating	_______

Evaluator's comments ____

____

____

Introduction

Many service facilities use forms to support their service work. Such forms may identify an engine, describe the performance problems or repair requirements, record work accomplished and parts installed, or otherwise document the work performed. These forms may be consolidated or may exist as separate documents. Even when the forms are consolidated, many facilities use a tag that is attached to each engine. These tags often list information about the engine. Such a form is illustrated on the following page. The service technician must use engine-identification and inspection skills to complete this form. Reference materials, experience, engine labels, inspection tools, and other resources aid the technician in completing the form.

Exercise

Directions

Read Student Supplement 2, "Outboard-Engine Construction." Your instructor will provide you with several outboard engines. Make one photocopy of the form on the following page for each engine your instructor provides. Using the skills you have developed and other resources available in your classroom, complete an engine-information form for each assigned engine.

Assignment Sheet 3

Engine-Information Form

Dealer's name ______________________________
Dealer's address ______________________________
Owner's name ______________________________
Technician's name ______________________________

Serial number ______________ Model number ______________
Horsepower/kw ______________ Date of manufacture ______________
Date of purchase ______________ Approximate hours used ________
Displacement (cu. in./liters) __________ Fuel injection: ☐ Yes ☐ No
Two-stroke-cycle engine ☐ Four-stroke-cycle engine ☐
Manual start ☐ Electric start ☐
Oil injection ☐ Power trim ☐
Number of cylinders ______________________
Recommended idle rpm ______________________
Recommended fuel ______________________
Recommended oil ______________________

Comments:

Operation and Service of Engine-Support Systems
Unit 2

Objective Sheet

Unit objective

After completing this unit, the student should be able to describe the design and operation of the engine-support systems used in outboard engines and perform routine service procedures on such systems. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific objectives

After completing this unit, the student should be able to

1. Define the term *engine-support system.*
2. List the major engine-support systems used in outboard engines.
3. Complete statements that describe the typical fuel systems used in outboard engines.
4. Match types of fuels used in outboard engines to their correct applications.
5. Describe the factors considered in the design of outboard-engine fuel tanks.
6. List probable causes of fuel-system problems.
7. Complete statements that describe the typical lubrication systems used in outboard engines.
8. Complete statements that describe the typical cooling systems used in outboard engines.
9. Describe the types of water pumps commonly used in outboard-engine cooling systems.
10. Complete statements about the principles of operation of volume-type water pumps.
11. Complete statements about the principles of operation of pressure-type water pumps.
12. Complete statements about the principles of operation of outboard-engine ignition systems.
13. Match types of tests performed on outboard-engine ignition systems to their correct purposes.
14. Match tools and instruments used to test ignition systems to their correct purposes.
15. List probable causes of ignition-system problems.
16. Complete statements that describe the typical starting systems used in outboard engines.
17. Complete statements that describe the typical charging systems used in outboard engines.
18. State the purpose of battery isolators.
19. Describe the typical exhaust systems used in outboard engines.

Objective Sheet

20. List the probable causes of engine overheating.
21. Define the typical tasks performed for engine tune-ups.
22. State guidelines for performing engine tune-ups.
23. Select the correct fuel and oil for outboard-engine applications. (Assignment Sheet 1)
24. Determine parts and specifications for engine-support systems. (Assignment Sheet 2)
25. Determine outboard-engine tune-up specifications and parts requirements. (Assignment Sheet 3)
26. Interpret an outboard-engine troubleshooting chart. (Assignment Sheet 4)
27. Fuel, start, operate, and shut down outboard engines. (Job Sheet 1)
28. Perform routine maintenance on fuel systems. (Job Sheet 2)
29. Repair fuel systems. (Job Sheet 3)
30. Perform routine maintenance on lubrication systems. (Job Sheet 4)
31. Repair lubrication systems. (Job Sheet 5)
32. Perform routine maintenance on cooling systems. (Job Sheet 6)
33. Repair cooling systems. (Job Sheet 7)
34. Perform routine maintenance on ignition systems. (Job Sheet 8)
35. Repair ignition systems. (Job Sheet 9)
36. Perform routine maintenance on starting systems. (Job Sheet 10)
37. Repair starting systems. (Job Sheet 11)
38. Perform routine maintenance on charging systems. (Job Sheet 12)
39. Repair charging systems. (Job Sheet 13)
40. Perform minor tune-ups. (Job Sheet 14)
41. Perform major tune-ups. (Job Sheet 15)
42. Troubleshoot failure-to-start in outboard engines. (Job Sheet 16)
43. Perform failure analysis on outboard engines. (Job Sheet 17)

Operation and Service of Engine-Support Systems
Unit 2

Information Sheet

1. **Definition of the term *engine-support system***

Note: In Unit 1, you reviewed the outboard-engine designs, including the power-production components, pistons, cylinders, and valves. In order for the power-production components to operate properly, a number of other systems are required to support and sustain engine operation. For the most part, these systems are the same as equivalent systems used in other types of power product equipment (see the corresponding sections of *Power Product Equipment Technician: Engine Systems and Service*). However, there are some differences that you will study in this unit.

- **Engine-support system**—System that supports and sustains the operation of the engine

2. **Major engine-support systems used in outboard engines**

- **Fuel system** (see Objectives 3 through 6)
- **Lubrication system** (see Objective 7)
- **Cooling system** (see Objectives 8 through 11)
- **Ignition system** (see Objectives 12 through 15)
- **Starting system** (see Objective 16)
- **Charging system** (see Objectives 17 and 18)
- **Exhaust system** (see Objective 19)

3. **Description of the typical fuel systems used in outboard engines**

- The fuel system consists of a device for storing the fuel (the tank), the fuel lines, fuel filters (which often include water-separating filters), a fuel pump (or gravity feed), and a means of metering and delivering the fuel to the combustion chamber.

  Note: *Metering* is the process of mixing the fuel with air to obtain a combustible mixture.

- Most outboard engines use carburetors that are essentially the same as those used in other types of power product equipment. However, some larger engines use computer-controlled fuel-injection systems.

- The majority of carbureted systems use diaphragm fuel pumps, though some smaller engines have fuel tanks mounted on the engine with gravity fuel flow.

- Most fuel injectors are not internally serviceable and must be replaced if not operating properly. Fuel-delivery problems may result from dirty injectors or from problems in the electronic-control unit while the injectors themselves are performing properly.

  Note: In order to meet federal fuel-economy and emissions requirements, outboard-engine manufacturers are exploring various ways of improving fuel systems, including advanced injection systems. Technicians will have to monitor technological developments in these areas to stay current.

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- Another portion of the fuel system that is likely to differ in outboard engines as opposed to land-based equipment is the fuel tank. While some small outboard engines have the fuel tank integrated into the power-head housing, many have a separate fuel tank that carries a relatively large quantity of fuel and is designed to survive the marine environment and movement of the boat while delivering a steady supply of uncontaminated fuel.

4. Types of fuels used in outboard engines and their applications

- **Leaded gasoline**—Used in gasoline engines designed before the late 1970s

  Note: Leaded gasoline is not generally available in North America. Outboard engines since the late 1970s have been designed to use unleaded fuel.

- **Unleaded gasoline**—Used in gasoline engines designed after the late 1970s

  Note: Modern outboard engines use unleaded gasoline. Manufacturers recommend octane ratings for the gasoline to be used as fuel in their engines. Technicians should observe these octane ratings when selecting the proper gasoline for an outboard engine.

- **Blended fuels**—Used to decrease the production of carbon monoxide in outboard-engine exhaust; are not recommended for use in most outboard engines

  Note: Blended fuels are a mixture of gasoline and an oxygenating substance, such as alcohol or ether. The purpose of the oxygenating agent is to decrease the production of poisonous carbon monoxide by increasing the amount of carbon dioxide in the engine exhaust.

  The disadvantage of blended fuels is that they do not provide as much power as straight gasoline and, in some cases, may increase the deterioration of rubber and plastic parts and may lead to the production of more deposits in the fuel system.

  Most outboard-engine manufacturers recommend that blended fuels not be used. If a blended fuel is used, additives are available to stabilize the fuel.

- **Diesel fuel**—Used only in diesel engines

- **Alcohol**—Used primarily as a fuel additive; only rarely used as a fuel

  Note: Although used as a fuel additive and as a fuel in some types of engines, alcohol is not routinely used as a fuel for outboard engines.

5. Factors considered in the design of outboard-engine fuel tanks and their descriptions

- **Corrosion resistance**—The tank must be able to withstand the marine environment
- **Filter system**—The tank or lines must prevent sediments from reaching the engine
- **Venting**—Fuel tanks must be vented to allow air to enter the tank as the fuel level goes down
- **Baffle systems**—Large fuel tanks often include baffles to prevent excessive sloshing of the fuel
- **Secure installation**—The tank must be securely installed to prevent the tank from coming loose as the boat travels
- **Primer system**—Many tanks will include primer bulbs to allow the manual pumping of fuel to the engine for cold starts

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6. Probable causes of fuel-system prcblems

- Empty fuel tank
- Closed or clogged fuel-tank air vent
- Contaminated fuel
- Incorrect fuel/oil mixture
- Leaky or weak fuel pump
- Clogged fuel line, screens, or filter
- Incorrect float setting
- Incorrect needle-valve settings or dirty needle valves

  Note: Most outboard engines are beginning to use fixed-orifice designs that are not adjustable.

- Binding of mechanical parts

7. Description of the typical lubrication systems used in outboard engines

- The lubrication system consists of a supply of oil and a means of circulating the oil around the moving parts of the engine.
- Two-stroke-cycle systems generally use oil mixed with the fuel. As the mixture is drawn into the crankcase, it lubricates the crankshaft and bearings. The cylinder walls in the combustion chamber are lubricated by the oil in the fuel that enters the combustion chamber.
- In two-stroke-cycle engines two principal ways are used to combine oil with the fuel. One way is to manually mix oil with the gasoline before filling the fuel tank, and another way is to use an oil-injection system that sprays oil into the fuel, often as the fuel enters the crankcase.
- Four-stroke-cycle engines generally flow oil over moving parts without mixing it with fuel. Four-stroke-cycle outboard engines are likely to use a pressurized oil system similar to those used on some multi-cylinder motorcycle, snowmobile, or garden-tractor engines.
- Lubrication systems in four-stroke-cycle engines include an oil reservoir, a pump that is usually driven by the crankshaft, oil channels to carry the oil to moving parts, and channels to return oil to the reservoir. Pressurized lubrication systems are also likely to have oil filters.

8. Description of the typical cooling systems used in outboard engines

Note: Perhaps the biggest difference in engine-support systems between outboard engines and those used on other types of land-based power product equipment is the cooling system. Outboard engines are generally water cooled, while most other power product equipment engines use air movement for cooling. Water cooling is a more-efficient means of cooling than air cooling because of water's ability to better transfer heat. However, to carry a supply of water and the system required to circulate it around an engine could easily double the weight of land-based equipment. Boats, though, have a ready source of water that does not have to be transported with the boat.

Information Sheet

- Typically, an outboard-engine cooling system will consist of an intake port below the normal water level, a screen to prevent debris from entering the cooling system, a pump to move the water through the cooling system, a thermostat to stop the flow of water when the engine is cold or adequately cooled, channels—called a *water jacket*—through which water circulates in contact with the heated components of the power head, and an exhaust port that removes heated water from the engine.

- Cooling-system designs may vary in details such as the location of the thermostat, the type of pump used, and other features, but they all operate in the same general way.

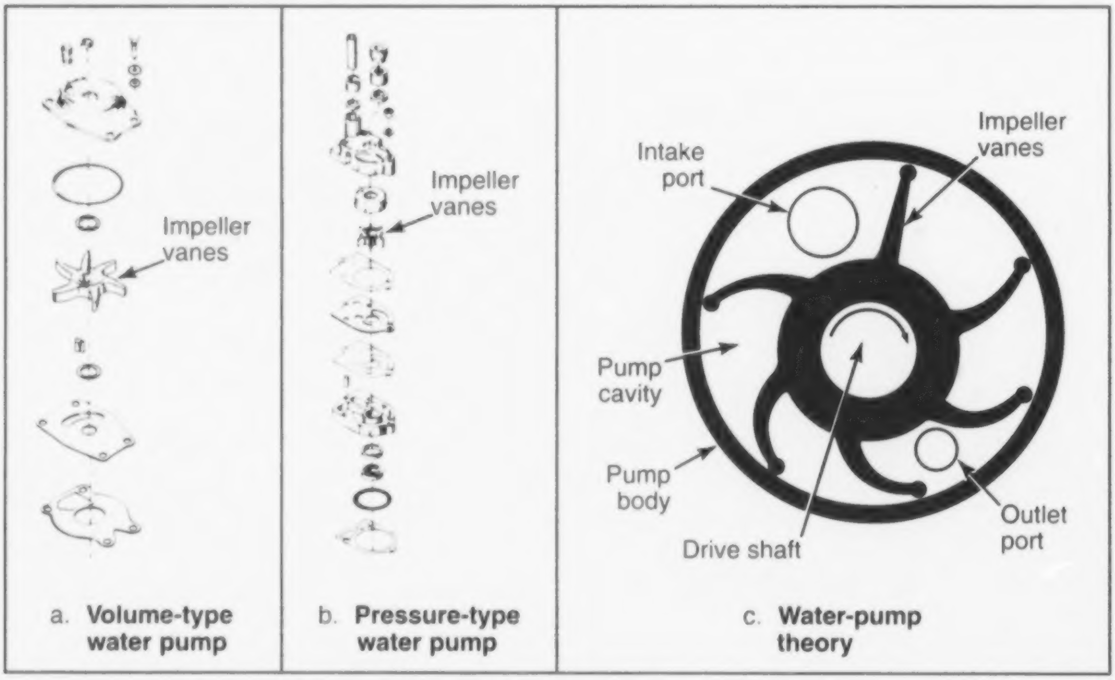
9. Types of water pumps commonly used in outboard-engine cooling systems and their descriptions

Note: Two types of water pumps are commonly used in the cooling systems of outboard engines: (1) the volume-type water pump and (2) the pressure-type water pump. Both types operate in basically the same way, but they differ in the length of their impeller vanes. The volume-type water pump has longer impeller vanes so that a larger volume of water is moved through the water pump. The pressure-type water pump has shorter impeller vanes so that, at the same engine speed, a smaller volume of water is moved through the water pump, but it will apply more pressure. (See Figure 1.)

- **Volume-type water pump**—Has longer impeller vanes so that it moves a larger volume of water through the pump (see Figure 1-a)

- **Pressure-type water pump**—Has smaller impeller vanes so that it moves a smaller volume of water through the pump; however, it applies more pressure (see Figure 1-b)

Figure 1: Common types of water pumps



a. **Volume-type water pump**

b. **Pressure-type water pump**

c. **Water-pump theory**

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10. **Principles of operation of volume-type water pumps** (see Figure 1-c on the previous page)

- The drive shaft passes through the pump body at an offset from the center of the pump so that one portion of the pump is larger (has a larger volume) than the other portion.
- Water enters into the large portion of the pump.
- The drive shaft rotates the impeller so that water is moved around the pump from the large portion to the small portion; because of the decreased volume in the small portion, the pressure on the water increases.
- Water flows through the outlet port and undergoes a further increase in pressure and speed because the outlet port is smaller in diameter than the inlet port.

11. **Principles of operation of pressure-type water pumps** (see Figure 1-c on the previous page)

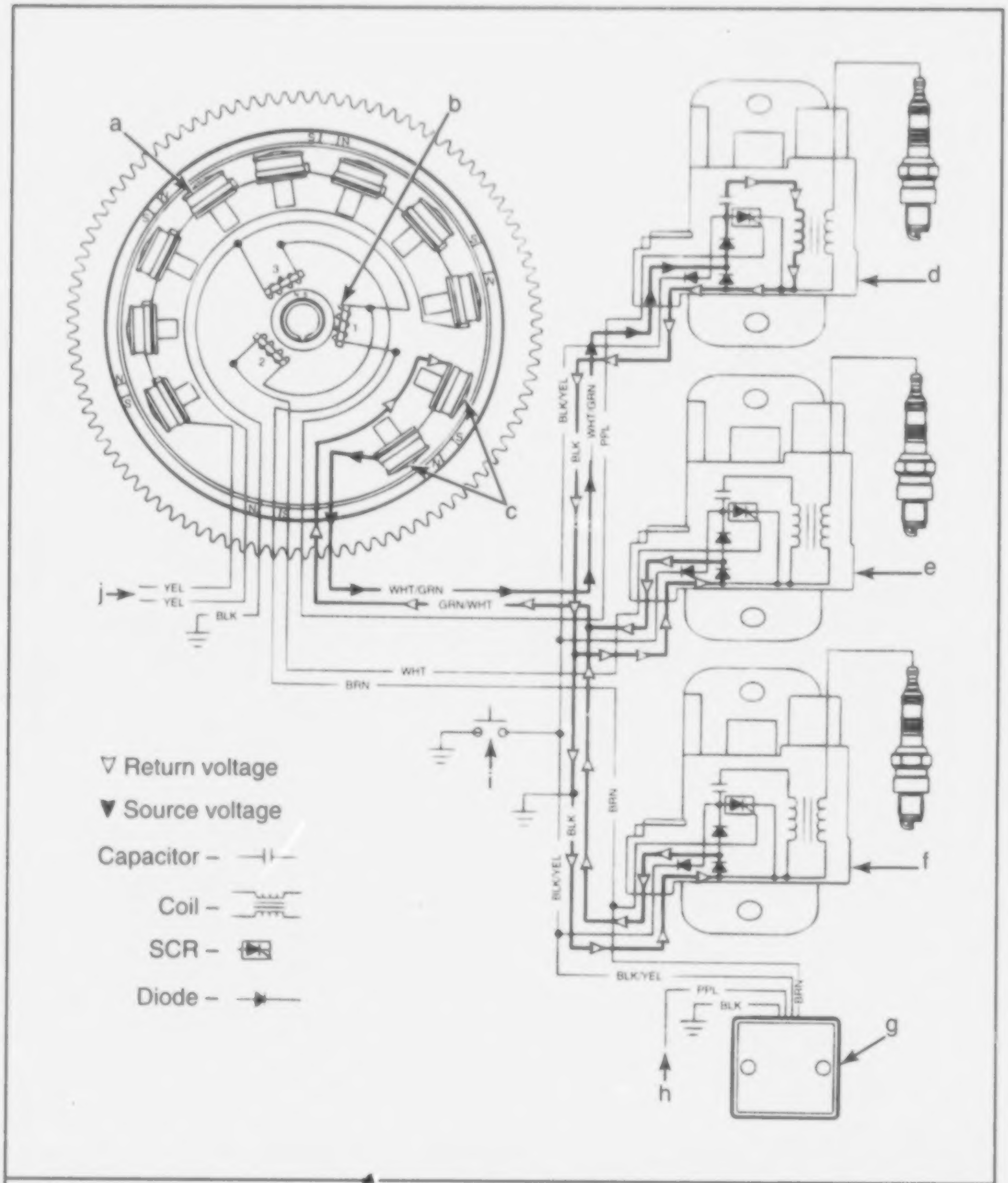
- The drive shaft passes through the pump body at an offset from the center of the pump so that one portion of the pump is larger (has a larger volume) than the other portion.
- Water enters into the large portion of the pump.
- The drive shaft rotates the impeller so that water is moved around the pump from the large portion to the small portion; because of the decreased volume in the small portion, the pressure on the water increases.
- Water flows through the outlet port and undergoes a further increase in pressure and speed because the outlet port is smaller in diameter than the inlet port.
- Because of the small pump-body volume, the movement of the water from the inlet to the outlet port happens very quickly and, though the volume of water moved is small, the change in pressure occurs rapidly.

12. **Principles of operation of outboard-engine ignition systems**

Note: While there are many variations in the specific designs of ignition systems, the general operation of these systems is quite similar. All modern outboard-engine ignition systems are designed to deliver a controlled level of current to each spark plug at an appropriate time so that combustion can occur for efficient power production. For this to happen, there must be a means of producing electrical current, a method of ensuring that the current is adequate for igniting the fuel mixture, and a way of delivering the current to the spark plug at the correct time. Even though the individual components of a given ignition system may differ from other systems, the components of each will work together to perform these basic functions. The descriptions on page 43 detail the operation of typical outboard-engine ignition-system components and, through notes, describe ways in which such circuits are implemented.

Figure 2 on the next page shows an electrical schematic for a typical ignition system for a modern three-cylinder engine and is provided to assist you in following the operational description.

Figure 2: Typical ignition-system electrical schematic


a
b
c
d
e
f
g
h
i
j
YEL
YEL
BLK
WHT/GRN
GRN/WHT
WHT
BRN
BLK/YEL
BLK
WHT/GRN
PPL
BRN
BLK/YEL
PPL
BLK
BRN
▽ Return voltage
▼ Source voltage
Capacitor –
Coil –
SCR –
Diode –

a. Battery charging coils
b. Trigger coils
c. Capacitor charge coils
d. CDM #1
e. CDM #2
f. CDM #3
g. Rev. limiter (not used on all models)
h. To ignition switch
i. Stop switch
j. To voltage regulator

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- **The flywheel is mounted to the end of the crankshaft and rotates with it.**
- **Magnets are mounted on the flywheel.**
- **A generating coil is mounted next to the path of the rotating flywheel.**

  Note: A coil consists of a winding of wire around a metal core, usually iron.

- **As the magnets on the flywheel move past the generating coil, electrical flow is induced in the windings of the coil.**

  Note: When a magnetic field moves over a coil or a coil passes through a magnetic field, electricity begins to flow through a process called *induction*.

- **The induced electricity alternates flow direction (alternating current) as the polarity of the rotating magnets switch between north and south poles.**
- **The electrical flow is directed through a rectifier circuit, where it is converted to direct current.**

  Note: A rectifier circuit allows electrical flow in one direction only. Thus, all of the electricity passing through a rectifier becomes direct current. Most outboard-engine ignition systems use a semiconductor device called a *diode* to rectify the electrical output of the generating coil. One or more diodes may be used to perform rectification.

- **The converted electrical current flows to a capacitor, where it is stored.**

  Note: A capacitor is a device that is capable of storing an electrical charge and then releasing it. Capacitors (condensers) used on early outboard engines consisted of rolled-foil plates that could hold a charge. Modern ignition-system capacitors are semiconductor devices.

- **The ignition system monitors engine conditions to determine the appropriate time to send current to the spark plug.**

  Note: The simplest method for monitoring engine conditions is to use a physical means of keeping track of where the flywheel is in its rotation, which in turn indicates the position of the piston or pistons in the combustion cycle. Early outboard engines used a distributor with a special switch called a *breaker* in it. The distributor contained a shaft that was geared to the crankshaft. A cam on the distributor shaft opened and closed the breaker switch to regulate the flow of current to the ignition coil. Modern outboard engines use distributorless or breakerless ignition systems that monitor engine conditions with special sensors or have another coil in which current flow is induced by the rotation of the flywheel at the appropriate time. For those systems that use sensors, conditions such as flywheel position, engine temperature, and engine rpm are monitored and the information provided to a computer in the engine.

- **A trigger pulse is generated at the appropriate time.**

  Note: For those systems that use a trigger coil, the position of the flywheel trigger-coil magnets determine when the trigger pulse is generated. Current is induced in the coil and provides power to close a switch in the ignition system. For those systems that use electronic sensors to monitor engine conditions, the ignition-system control module determines when to generate the trigger pulse to generate the properly timed spark. The current used is normally stored in another capacitor or generated by another portion of the circuit in multiple-cylinder engines.

- **The trigger pulse causes a switch to close.**

  Note: Most outboard-engine ignition systems use a silicon-controlled rectifier (SCR) as a switch in the capacitor-discharge circuit. SCRs are said to be *gated*—electrical flow is blocked until the trigger pulse closes a path of electrical flow in the SCR.

- **The closed switch allows the capacitor to discharge.**

  Note: Because ignition results from the electrical current discharged by the capacitor, this type of system is generally referred to as a *capacitor-discharge ignition* or *CDI*. Virtually all modern outboard engines use some sort of CDI system.

- **The capacitor current flows to the primary winding of the ignition coil.**

- **As electricity flows through the primary winding of the ignition coil, current is induced in the secondary winding of the ignition coil.**

  Note: The ignition coil consists of two sets of windings referred to as the *primary* and *secondary windings*. The two windings are positioned very near each other. Because a magnetic field forms around electric currents, the flow of electricity through the primary winding of the ignition coil induces current in the secondary winding.

- **The voltage in the secondary winding increases enough to overcome the resistance of the spark gap, it flows through the spark-plug lead wire, arcs across the gap, igniting the fuel mixture, and flows to ground.**

  Note: The secondary winding has more coils in it than the primary winding. As a result, a higher voltage is induced as the primary circuit flows past a greater number of coils. For this reason, the ignition coil is sometimes referred to as a *transformer* and specifically a *step-up transformer* because it transforms the capacitor current to a higher voltage. In this way, the engine can be made simpler and lighter because only a few volts are required from the generating coil.

- **The process repeats itself with each rotation on the flywheel, generally resulting in one complete combustion cycle for each cylinder with each revolution.**

  Note: Over the years, ignition systems have become more and more electronically based. Many of these electronic components are housed together in one component or module. For example, it is common to have the rectifier, SCR, and capacitor in a single unit. These modules are known by a number of names, including *capacitor-discharge unit* (CDU), *capacitor-discharge module* (CDM), *power pack, electronic control unit* (ECU), *switchbox*, and others. Many newer engines, especially larger ones, have on-board computers that control not only the ignition system but also fuel-injection and other operational processes.

13. **Types of tests performed on outboard-engine ignition systems and their purposes**

Note: The specific tests to be performed on a particular ignition system will vary from one type of system to another. The tests listed here are typical of most ignitions. Many of the tests may be done at either the system or the component level. Tests are performed with the engine specifically configured for the test. For example, with a given test, certain components may be disconnected or connected to test equipment. Often, the spark-plug wires are disconnected to prevent the engine from starting while the engine is cranked. Such tests may be referred to as *cranking tests*. Other tests are conducted with the engine operating and are referred to as *running tests*.

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- **Continuity test**—Verifies electrical flow from one point in a circuit to another, including from one connector to another in a component

  Note: The ignition is basically a circuit through which electricity flows. Continuity testing shows whether current is present at points along the circuit when electrical flow is or is not expected.

- **Resistance test**—Checks the ease with which current flows between two points in a circuit

  Note: Resistance is opposition to electrical flow in a circuit. If resistance is too high in a circuit, electricity will not flow. With today's electronic ignition systems, resistance is a critical value because semiconductor devices use resistance to perform switching operations—that is, preventing electrical flow until the current reaches a certain level.

- **Output test**—Checks the value of a signal being produced by a sensor or other system component

  Note: Output tests are normally a measure of voltage. Current is applied to a component or point in a circuit. If the circuit is working normally, the voltage on the output side of that component or point can be expected to fall within a range of voltage values, such as less than 5 volts or 2.3 to 2.6 volts. Values outside the expected range may indicate a defect in the component.

- **Spark-plug-gap test**—Verifies that current flows between the electrodes of the spark plug

- **Service-code retrieval**—Checks diagnostic codes stored in the engine's computer memory

  Note: Some outboard engines are equipped with computers that help control the operation of the engine under varying conditions. Computers are most commonly found on engines equipped with fuel-injection systems where they are used to control fuel flow and ignition timing and to monitor or control operation of other engine-support systems. The codes are numbers or light-flash patterns that indicate specific problems with engine performance in the systems monitored by the computer.

14. Tools and instruments used to test ignition systems and their purposes

Note: Some instruments are designed to perform only one specific type of test, such as using an ohmmeter for resistance testing. Others offer options for performing more than one type of test. For example, a multimeter can be used to check a number of electrical characteristics.

- **Continuity light**—Indicates whether or not current is present at a point in a circuit

- **Ammeter**—Measures electrical current in a circuit and is used to perform continuity tests

- **Ohmmeter**—Measures resistance and is used to perform resistance tests

- **Voltmeter**—Measures voltage and is used to perform output tests

- **Peak-reading voltmeter**—Measures voltage and indicates the highest level of voltage present in an alternating current

- **Multimeter**—Measures current, resistance, and voltage and is generally suitable for a variety of tests

- **Spark-plug-gap tester**—Verifies spark across a spark plug

Information Sheet

- **Special equipment**—Perform specific tests or allow engine systems to be connected to other test equipment

  Note: Many manufacturers offer special test instruments necessary to perform some measurements of their engines' performance. For example, an adapter may be necessary to connect a component to some test equipment. Jumper wires or bypass connectors may be specified for some tests. As a convenience to the service technician, manufacturers also provide electronic test instruments that perform functions similar to common devices, such as multimeters, but with functions and capabilities tailored specifically for their engines.

- **Service-code retrieval system**—Reads and erases codes stored in the memory of the engine computer

  Note: Service codes are generally retrieved by specific service equipment or through the use of a personal computer loaded with special software that allows the computer to read the codes and collect other information from the engine computer.

15. Probable causes of ignition-system problems

- Incorrect timing
- Broken or damaged spark plug
- Fouled spark plug
- Improperly gapped spark plug
- Incorrect spark plug
- Ignition points not properly gapped
- Ignition points burned or dirty
- Weak or damaged coil
- Weak condenser
- Cracked distributor cap or rotor
- Faulty electronic ignition component
- Loose or broken ignition wires
- Loose or worn magneto plates (strator plates)
- Worn cam or cam follower
- Poor grounding

16. Description of the typical starting systems used in outboard engines

- Outboard engines generally use one of two methods to begin the internal-combustion process by turning the flywheel. The flywheel can be turned manually using any of the rope-rewind systems or electrically by a motor powered from a battery.

Information Sheet

- The most likely difference between an electrical starting system on an outboard engine and that used on land-based equipment is that special precautions are used to protect marine batteries from their environment and to provide grounding to them. In most land-based equipment, the starting system and other battery-powered equipment are grounded through the equipment chassis to complete the ground circuit to the battery. This approach is not possible on boats because the chassis or hull is made of a nonconductive material such as wood or fiberglass or of a conductive material such as aluminum that would just as easily conduct the current into the water.
- Outboard-engine starters must be sealed to prevent sparks from igniting fuel vapors.

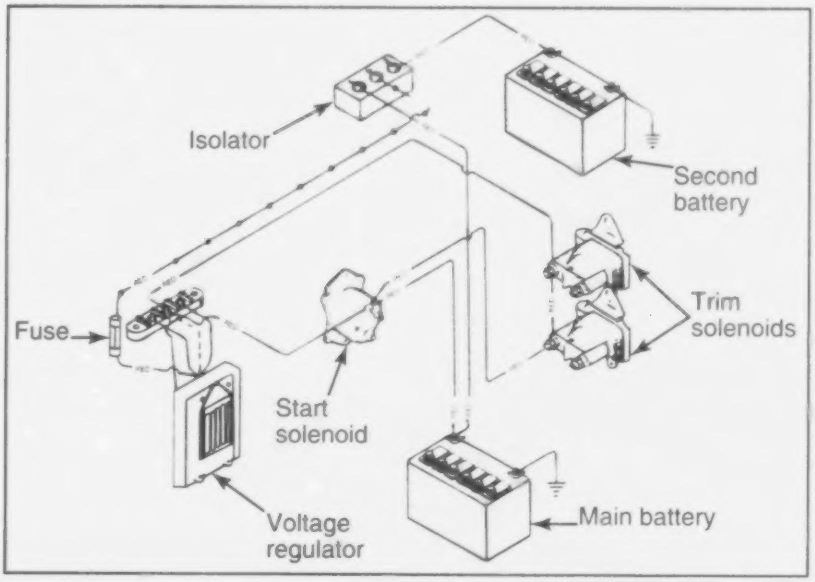
17. Description of the typical charging systems used in outboard engines

- The purpose of the charging system is to maintain an adequate level of charge in the battery so that the boat can be started and other battery-powered systems operated.
- As with other types of power product equipment, charging is generally accomplished through the use of electricity generated by the rotation of the flywheel.
- Some outboard engines have a separate belt- or shaft-driven alternator.

18. **Purpose of battery isolators**—To allow the charging system to charge both the starting battery and an auxiliary battery at the same time while preventing accessories that are connected to the auxiliary battery from drawing current from the starting battery

Note: Batteries provide a convenient means of supplying power to electrical instruments and accessories. However, to maintain these power sources, there must be a means of recharging them. To simplify the charging function, multiple batteries generally use a single charging system. Yet, this approach can cause the discharge of the starting-system battery when the engine is not running. To prevent this condition, many outboard engines use a battery isolator, as shown in Figure 3.

Figure 3: Battery isolator



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19. Description of the typical exhaust systems used in outboard engines

- Except for the exhaust valve or port, most outboard-engine exhaust systems do not contain moving parts.
- Generally, there is a tube that connects the exhaust port of the combustion chamber through the midsection to an exit port below the water level.
- Mufflers and similar devices are not usually required.

20. Probable causes of engine overheating

- Inadequate lubricant
- Clogged water intake
- Faulty water pump
- Defective thermostat
- Incorrect thermostat
- Clogged or corroded water passages
- Improper ignition timing
- Leaking head gasket or cracked head

21. Typical tasks performed for engine tune-ups and their definitions

Note: Many types of service procedures are referred to as a *tune-up.* Some tune-up tasks may be performed as routine service or as part of restoring an engine to service at the beginning of the season. Basically, a tune-up is a systematic service procedure to return an engine to its expected performance level short of trying to restore parts to a like-new condition. A tune-up must address those systems that affect power production, including the fuel, ignition, and lubrication systems as well as the mechanical operation of the engine.

- **Service air box**—Clean or replace the air box to provide a clean air supply to the carburetor

  Note: Many outboard engines have air-intake systems that route air to the carburetor. This area must be kept clean and free of obstructions.

- **Service fuel system**—Adjust the carburetor float level, clean fuel orifices and jets, replace the fuel filter, test the fuel pump or injectors to ensure delivery of a correct quantity of clean fuel for the compression-ignition stroke

- **Service lubrication system**—Change the oil and filter to provide adequate lubrication and to ensure proper sealing of the piston rings

  Note: The lubrication system helps to reduce friction so that engine parts do not increase the load on the engine. Oil is also important in helping to reduce compression leaks. For two-stroke-cycle engines, the fuel and oil are mixed together so that the technician needs to ensure that the fuel and oil are properly mixed and that the right oil is used.

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- **Service ignition system**—Adjust the armature air gap, adjust the breaker gaps, clean and regap or replace the spark plugs, and set the ignition timing to provide sufficient spark at the correct time during the internal-combustion process

- **Clean engine and ensure proper assembly**—Remove dirt and grime from the engine to ensure that moving parts are not obstructed and to allow proper cooling; ensure that parts move without binding, that fasteners are properly tightened, and that gaskets do not leak

  Note: Technicians should clean the engine as part of any service procedure and particularly with tune-ups. A clean engine not only runs better, but dirt and grime can hide damage, leaks, and wear. Additionally, cleaning an engine is a good professional practice that will impress customers. Some facilities make a point of cleaning some internal parts during a tune-up, including cleaning carbon off the combustion chamber.

22. Guidelines for performing engine tune-ups

Note: The overall goal of a tune-up is to prepare the engine for service with maximum power and efficiency. Obviously, adjustments in one system may affect the performance of other systems. Therefore, a tune-up should be carefully planned and done systematically.

- **Ensure that the battery is fully charged.**

- **Ensure that the spark plug is clean, properly gapped, and fully seated, and that it is the correct spark plug for the engine.**

- **Ensure that the fuel is fresh.**

- **Ensure that there is adequate lubrication.**

  Note: If working on a two-stroke-cycle engine with an oil-injection system or a four-stroke-cycle engine, check the oil level and cleanliness. If in doubt, replace the oil. For other two-stroke-cycle engines, ensure that the fuel/oil mixture is of the proper ratio and consists of fresh fuel and oil. If in doubt, replace the fuel/oil mixture.

- **Ensure that all filters are in place, properly installed, and clean.**

- **Ensure that the engine is clean and can obtain adequate air.**

- **Perform preliminary checks of the ignition timing and fuel systems.**

  Note: Observe the easily checked features of the ignition and fuel systems, such as binding in the throttle linkage, clogged fuel filters, drastically misaligned timing marks, loose flywheels, etc.

Operation and Service of Engine-Support Systems
Unit 2

Assignment Sheet 1—Select the Correct Fuel and Oil for Outboard-Engine Applications

Name ______________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	______
Minimum of 85 percent of answers are correct.	______
Overall rating	______

Evaluator's comments ______________________________

____

____

Introduction

An outboard engine cannot operate properly unless the correct fuel is used. For two-stroke-cycle engines, this means the specified fuel and oil mixture. For four-stroke-cycle engines, the correct oil must be used in the lubrication system. The technician must use the type and viscosity of oil recommended by the manufacturer. Some manufacturers recommend oils specifically formulated for marine engines. When servicing an engine that is not operating properly, technicians need to consider the possibility that the operator has used the wrong fuel mixture or that the fuel is old or contaminated. If service is required, many facilities make it a practice to replace the fuel, especially as a lot of service procedures include draining the fuel system as a safety measure. In any case, technicians must understand the requirements for fuel and fuel mixtures. This assignment sheet will provide you with practice in selecting fuel and oil for outboard-engine applications.

Exercise

Directions

In each of the following sections, Parts A through E, use the resources available in your facility to determine fuel and oil specifications.

In Question 1 of each section, provide the specifications requested. In Question 2 of each section, your instructor will fill out the engine information, and then you will provide the specifications requested.

In both questions in each section, provide information for the latest available model of the engine. For example, if specifications differ for engines manufactured before 1985 and those manufactured after 1985, provide specifications for those with the later manufacture date.

Assignment Sheet 1

Part A

1. What fuel/oil-mixture ratio should be used for each of the following engines, and what type of oil is recommended?

	Engine	Fuel/oil ratio	Recommended oil
a.	Chrysler 15 hp		
b.	Johnson 18 hp		
c.	Mariner 28 hp		
d.	Suzuki DT8 hp		
e.	Yamaha 2 hp		

2. Your instructor will complete the "Engine" column in the table below. What fuel/oil-mixture ratio should be used for each of these engines, and what type of oil is recommended?

	Engine	Fuel/oil ratio	Recommended oil
a.			
b.			
c.			
d.			
e.			

Part B

1. Many manufacturers recommend that a different fuel/oil mixture be used for an engine's initial break-in period. What is the recommended fuel/oil-mixture ratio and the duration of the break-in period for each of the engines you researched in Item 1?

	Engine	Fuel/oil ratio	Duration of break-in period
a.	Chrysler 15 hp		
b.	Johnson 18 hp		
c.	Mariner 28 hp		
d.	Suzuki DT8 hp		
e.	Yamaha 2 hp		

2. Your instructor will complete the “Engine” column in the table below. What is the recommended fuel/oil-mixture ratio and the duration of the break-in period for each of these engines?

	Engine	Fuel/oil ratio	Duration of break-in period
a.			
b.			
c.			
d.			
e.			

Part C

1. What type and weight of gear oil is recommended for the following engines?

	Engine	Gear-oil type	Gear-oil weight
a.	Chrysler 25 hp		
b.	Force 15 hp		
c.	Evinrude 7.5 hp		
d.	Mariner 8 hp		
e.	Mercury 3.5 hp		

2. Your instructor will complete the “Engine” column in the table below. What type and weight of gear oil is recommended for these engines?

	Engine	Gear-oil type	Gear-oil weight
a.			
b.			
c.			
d.			
e.			

Assignment Sheet 1

Part D

1. What octane rating of gasoline is recommended for the following engines?

	Engine	Octane rating
a.	Evinrude 4.5 hp	
b.	Mariner 2 hp	
c.	Mercury 3.5 hp	
d.	Suzuki DT3.5	
e.	Yamaha 4 hp	

2. Your instructor will complete the "Engine" column in the table below. What octane rating of gasoline is recommended for these engines?

	Engine	Octane rating
a.		
b.		
c.		
d.		
e.		

Part E

1. The following engines are four-stroke-cycle designs. What lubricant is recommended for normal operation when an environmental temperature of 50°F (27°C) is the expected low?

	Engine	Oil	Weight
a.	Honda 15 hp		
b.	Evinrude 15 hp		
c.	Yamaha 25 hp		
d.	Mercury 18 hp		

Assignment Sheet 1

2. Your instructor will complete the "Engine" column in the table below. What lubricant is recommended for normal operation of these engines when an environmental temperature of 50°F (27°C) is the expected low?

	Engine	Oil	Weight
a.			
b.			
c.			
d.			

Operation and Service of Engine-Support Systems
Unit 2

Assignment Sheet 2—Determine Parts and Specifications for Engine-Support Systems

Name ______________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	______
Minimum of 85 percent of answers are correct.	______
Overall rating	______

Evaluator's comments ______________________

____

____

Introduction

While outboard engines resemble other types of power product equipment engines in many ways, there are many differences. One difference is that parts must be able to perform well in a marine environment. Therefore, even common parts such as spark plugs can be substantially different for marine applications. For these reasons, the technician must be especially careful to choose suitable parts and to maintain specifications that function well in a wet environment. In this assignment sheet, you will practice selecting parts and determining specifications for outboard engines and their related engine systems.

Exercise

Directions

Using the resources available in your facility, determine the part numbers and specifications requested. Write your answers on the blanks provided with each question.

Assignment Sheet 2

1. The legends and illustrations in Figure 1 and Figure 2 on the following pages show Evinrude/Johnson two-cylinder blocks and crankcases. The legend and illustration in Figure 1 show a 25-horsepower model, while the legend and illustration in Figure 2 show a 15-horsepower model. For each component listed below, write the number used in each illustration to indicate the manufacturer's part number.

	Component	25-hp part number	15-hp part number
a.	Cylinder and crankcase assembly		
b.	Bypass cover		
c.	Cylinder head		
d.	Outer exhaust		
e.	Cylinder-head gasket		

Figure 1: 25-horsepower model (legend)

Ref.	P/N	Name of part	Qty.
1	435942	Cylinder & crankcase assembly	1
2	331450	. Dowel, bearing	1
3	318622	. Screw, cylinder to crankcase	6
4	305070	. Taper pin	1
5	308353	. Stud	2
6	328932	. Nipple, recirculation hose	2
7	308354	. Stud, starter bracket	1
8	385111	. Check valve	1
9	305344	. Screen	1
10	335603	. Deflector, water passage	2
11	335602	. Deflector, water passage	1
13	314416	Bumper, spark-adjustment screw	1
14	319661	Gasket, bypass cover [3]	1
15	300646	Screw, bypass cover, small	6
16	335635	Cylinder-head assembly	1
18	307841	Sleeve, control lever	1
19	335762	Screw, spark adjustment	1
20	329241	Washer, bracket	2
21	434841	Thermostat assembly	1
22	329319	Gasket, thermostat	1
23	329419	Gasket, cylinder head [3]	1
24	305027	Screw, cylinder head	10
25	391465	Exhaust cover, outer	1
26	326712	. Nipple	1
27	324323	Gasket, exh. cover, outer to inner [3]	1
28	306418	Screw, exhaust cover	11
29	#	Hose, upper to lower crankcase, 12 in. (305mm)	1
30	584472	Ground-lead assembly	1
31	304454	Washer, bracket	2
32	302290	Lock washer, starter brackets	2
33	432424	Spark plug, Champion QL16V [1]	2
33	433627	Spark plug, Champion L16V [2]	2
34	308742	Screw, cover, thermostat boss	3
35	325340	Bracket, starboard	1
37	314979	Screw, cylinder to crankcase	8
38	303049	Cotter pin	4
39	438076	Control lever & pin	1
40	328741	Nut, spark adjustment	1
41	305831	Shim, control lever	2
42	331036	Screw, bearing clamp	4
43	331448	Bracket, control lever	1
44	331919	Bearing clamp, lever, lower	1
45	331918	Bearing, lever, lower	1
46	335326	Link, actuator cam	1
47	303398	Screw, starter bracket, stbd	1
48	325584	Spring, neutral-start plunger	2
49	325586	Retainer, spring	1
50	396163	Lever & roller assembly	1
51	†	Hose, ovbd. pump ind., 16 in. (406mm)	1
52	120590	Washer, lever & roller assembly	1
53	320107	Tie strap, hose	2
54	320374	Bracket, port	1
55	327673	Cover, cylinder head	1
56	303398	Screw, starter bracket & ground lead	1
58	320524	Bearing, control lever	1
59	327674	Gasket, cylinder-head cover [3]	1
60	303398	Screw, starter bracket, port	1
61	121731	Nut, starter-bracket mtg., stbd.	2
62	304221	Screw, collar to throttle-control rod	1
64	300646	Screw, cylinder-head cover	11
65	320786	Pivot pin	2
66	320156	Rod, throttle control	1
67	316368	Spring	1
68	332203	Screw, bypass cover, large	3
70	320523	Clamp, bearing	2
71	330151	Clamp, cable & temp. sw. lead	1
72	303715	Washer	2
73	304222	Collar	1
74	307565	Pin, rod, pivot pin	2
75	121731	Nut, starter-bracket mtg., port	1
76	328051	Spring, pressure relief	1
77	329241	Washer, starter-mtg. bracket	1
78	439912	Bypass, cover assembly	1
79	327443	Screw, starter lockout	1
80	326263	Exhaust cover, inner	1
82	330151	Clamp, lockout cable to cover	1
83	303398	Screw, bracket to exhaust cover	2
84	325332	Plunger	1
85	332610	Rubber mount, starter housing	3
86	333071	Cup, starter housing to mounts	3
87	551953	Washer, pivot pin	1
88	325326	Bracket, safety switch & cable	1
89	122147	Screw, bracket	1
90	328703	Washer, screw, bracket to engine	1
91	325589	Lever, starter lockout	1
95	326264	Gasket, exh. cover inner to c'case [3]	1
96	203688	Nut, idle stop	1
97	303398	Screw, bracket	2
98	331446	Bracket, idle stop	1
99	308038	Screw, idle stop	1
100	433941	Power-head-gasket set	1

# Cut to length from P/N 327229 – 0.0575 in. I.D., 25 ft. (7.6m) roll
† Cut to length from P/N 203909 – ⅛ in. I.D., 20 in. (508mm) long hose

[1] Radio noise-suppressor plug
[2] Optional
[3] Included in power-head-gasket set

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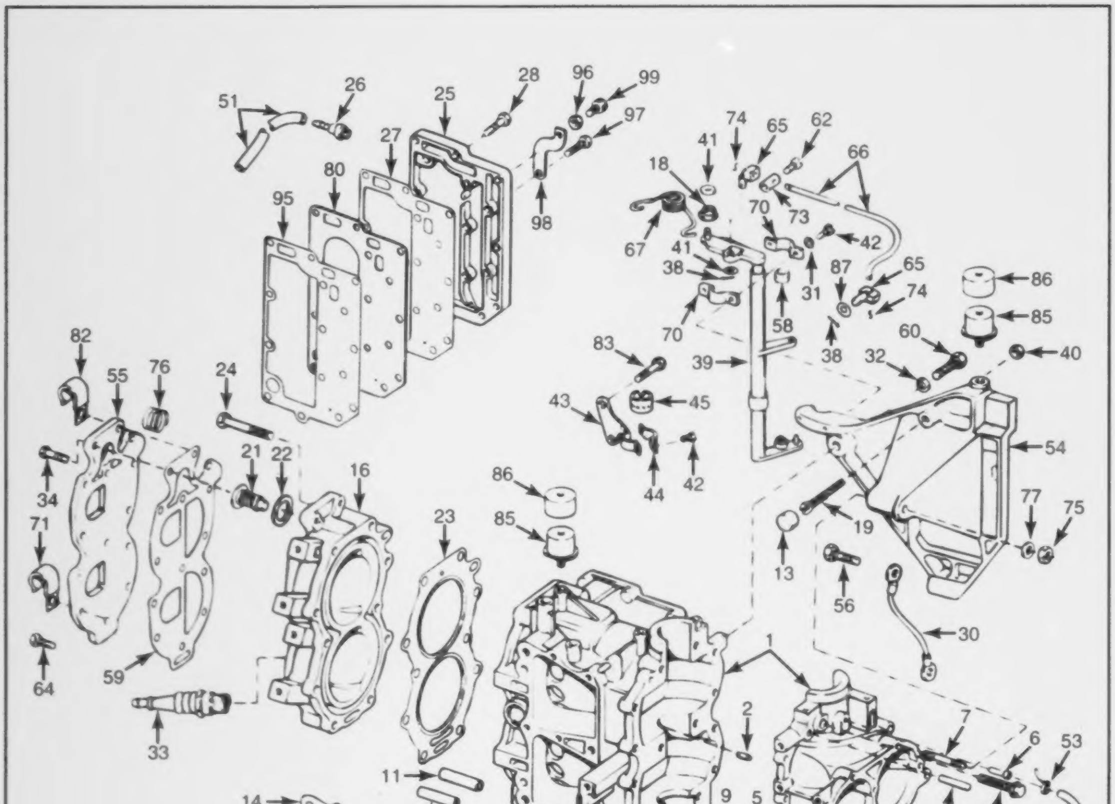
Assignment Sheet 2

Figure 1 (cont.): 25-horsepower model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Power-head-gasket set
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Assignment Sheet 2

Figure 2: 15-horsepower model (legend)

Ref.	P/N	Name of part	Qty.
1	5000034	Cylinder & crankcase assembly	1
2	304178	. Dowel, bearing	1
3	300402	. Taper pin	1
4	318622	. Screw, cylinder to crankcase	6
5	307551	Plug, flushing	1
6	311598	. Washer	1
7	338208	Bellcrank, shift rod	1
8	338234	Cover, thermostat	1
9	319537	Clip, bellcrank	1
10	336637	Bypass cover	1
11	302504	Pin, bellcrank to shift rod	1
12	319332	Gasket, bypass cover	1
13	300646	Screw, bypass cover	5
14	338221	Cylinder head	1
15	308017	Screw, bellcrank to shift rod	1
16	328724	Screw, detent spring	1
17	435226	Shaft & lever, shift	1
18	333706	Screw, cover	3
19	436195	Thermostat assembly	1
20	339713	Hose, overboard indicator	1
21	338222	Gasket, cylinder head	1
22	319226	Screw, cylinder head	6
23	435266	Exhaust cover, outer	1
24	328497	Exhaust cover, inner	1
25	318925	Gasket, exhaust cover	2
26	302288	Screw, exhaust cover	7
27	339208	Spacer, shift shaft	1
28	336947	Seal, cover	1
29	330212	Spring, backup, shift detent	1
30	330913	Spring, shift detent	1
31	437684	Spark plug, Champion QL82C	2
31	386941	Spark plug, Champion L77J4 [1]	2
31	432424	Spark plug, Champion QL16V [1]	2
31	433627	Spark plug, Champion L16V [1]	2
31	387633	Spark plug, Champion QL77J4 [1]	2
32	305650	Cotter pin, bellcrank	1
33	336179	Spring, thermostat	1
34	335521	Bushing, shift lever	2
35	305650	Cotter pin, shift link to bellcrank	1
36	306049	Screw, cylinder to crankcase	4
37	304380	Spring washer, bellcrank	1
38	330838	Screw, stop, W.O.T.	1
39	511421	Washer, throttle lever	1
40	338250	Spacer, throttle lever	1
41	437694	Diaphragm, thermostat	1
43	336178	Housing, thermostat	1
44	339692	Sleeve	1
45	336211	Spring, thermostat	1
46	336185	Washer, cover to diaphragm	1
47	435714	Throttle lever	1
48	338295	Link, throttle lever	1
49	338237	Pin, throttle cable to lever	1
50	305652	Screw, throttle lever	1
51	330838	Screw, throttle-lever stop	1
52	332203	Screw, bypass cover	1
53	336597	Overboard indicator	1
54	328702	Washer, bellcrank	1
55	316128	Bushing, starter link	1
56	436358	Power-head-gasket set	1

[1] Optional

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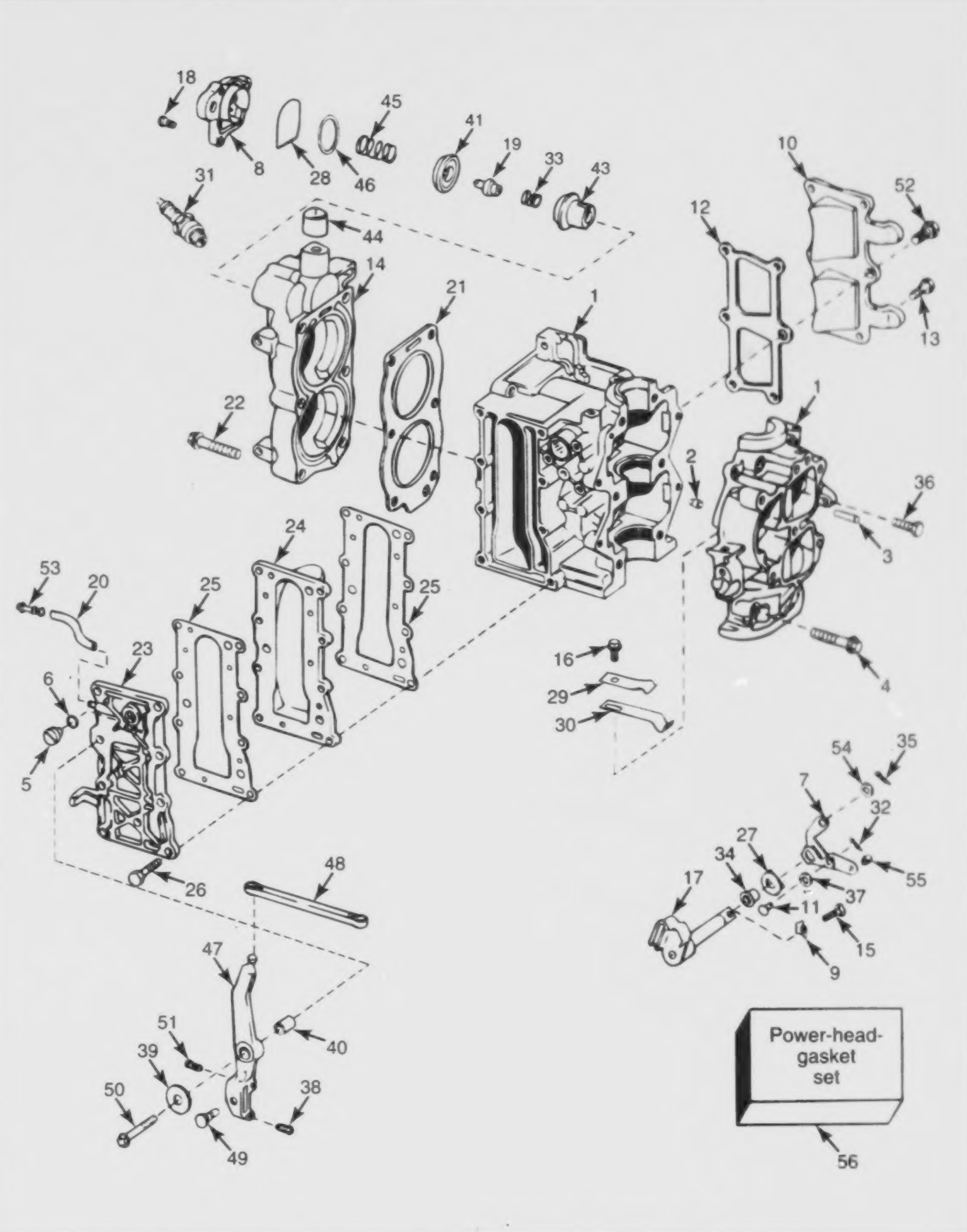
Assignment Sheet 2

Figure 2 (cont.): 15-horsepower model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Power-head-
gasket
set
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Assignment Sheet 2

2. An important adjustment in two-stroke-cycle engines is the clearance of the reed valve as determined by the reed-valve stop setting. Figures 3 and 4 on the next page show typical ways of illustrating the reed valves, with *A* indicating the required clearance. State the specified clearance for the intake reed valve for the engines listed below.

	Engine	Specified clearance
a.	Chrysler 25 hp	______________
b.	Mariner 5 hp	______________
c.	Mercury 7.5 hp	______________
d.	Suzuki DT3.5	______________
e.	Yamaha 8 hp	______________

3. What is the recommended spark plug and gap for the following engines?

	Engine	Spark plug	Gap
a.	Clinton K-150	______________	________
b.	Mariner 15 hp	______________	________
c.	Mercury 9.9 hp	______________	________
d.	Evinrude 20 hp	______________	________
e.	Tohatsu 5 hp	______________	________

Assignment Sheet 2

Figure 3: Reed-valve stopper clearance

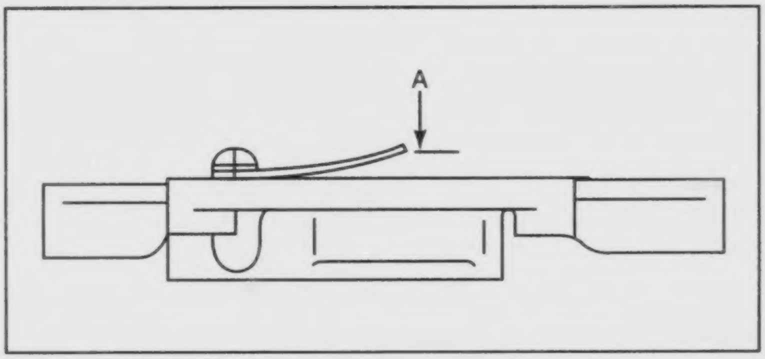


Figure 4: Reed-stop height

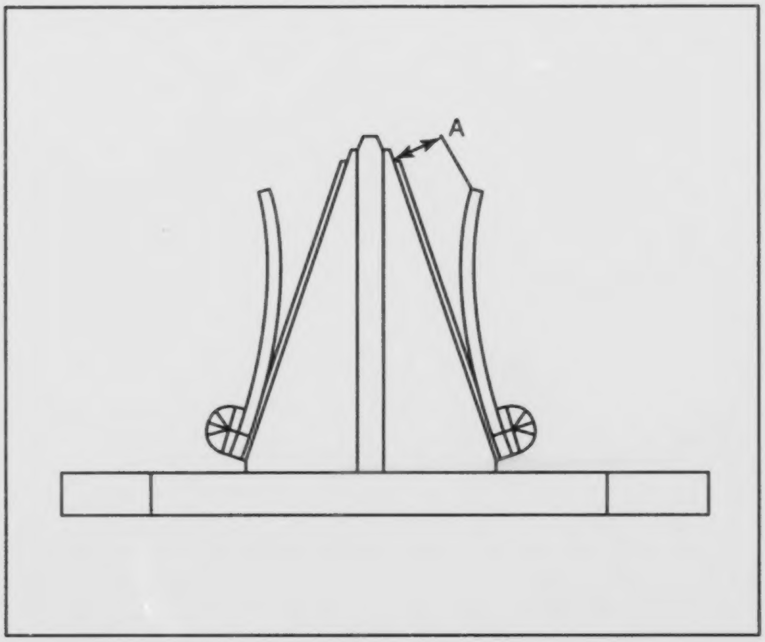


Figure 3 and Figure 4 reprinted with permission of Mercury Marine, Fond du Lac, Wisconsin.

Assignment Sheet 2

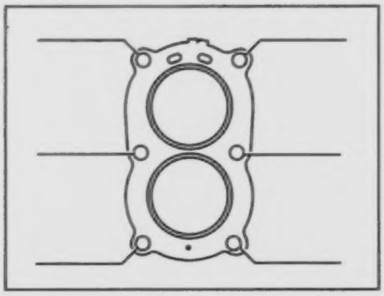
4. Determine the torque values and the torquing sequence for the following installations. List the torque values on the blank lines provided. Write the number for each fastener on the blank lines provided in the illustrations, beginning with "1" for the first fastener to be tightened, "2" for the second fastener, and so on.

   a. Johnson 4, cylinder-head retaining screws

      1) Torque value — ______________________________

      2) Torquing sequence

Figure 5



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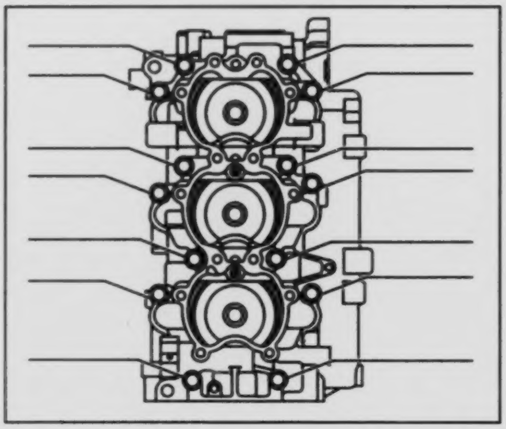
   b. Mercury 55/60 horsepower, cylinder-head retaining screws

      1) Torque value — ______________________________

      2) Torquing sequence

Figure 6



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Assignment Sheet 2

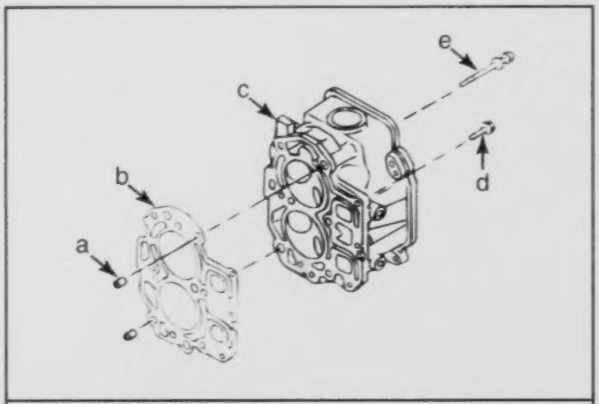
c. Mercury 9.9/15 horsepower, 4-stroke cylinder-head retaining screws

1) Torque value M6 x 25 bolts — ______________

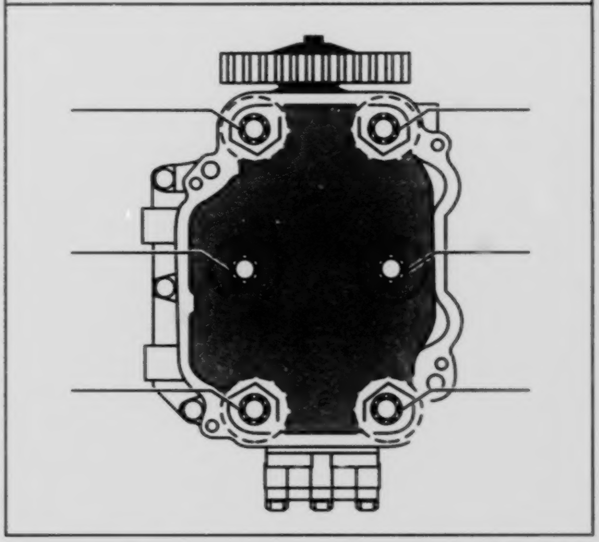
2) Torque value M8 x 78 bolts — ______________

3) Torquing sequence

Figure 7



a. Dowel pins (2)
b. Gasket—cylinder head (new)
b. Cylinder-head assembly
d. Bolts—cylinder head M6x25 (3)
e. Bolts—cylinder head M8x78 (6)



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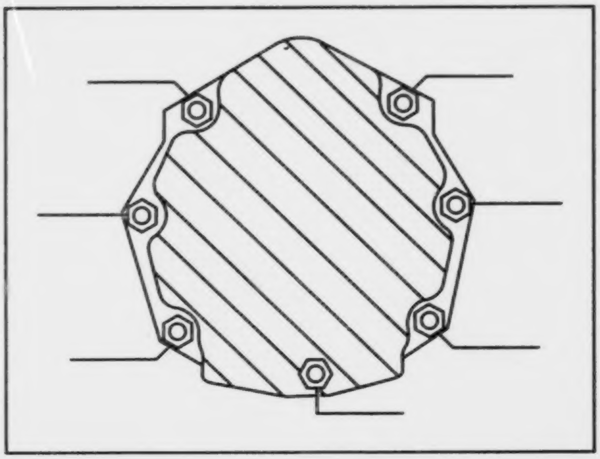
Assignment Sheet 2

d. Mercury V 3.4L, power-head retaining nuts

  1) Torque value — ______________________________

  2) Torquing sequence

Figure 8



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5. One of the critical adjustments on an outboard engine is setting the fuel level in the carburetor. There are numerous variations in making this setting and in how the fuel level is measured.

  a. Figure 9 on the next page shows how the carburetor float level is adjusted for Mercury/Mariner models 4 and 5 four-stroke engines after serial number OR000001. What should the measurement be?

  Measurement — ______________________________

  b. Figure 10 on the next page shows the adjustment for the carburetor float level for Johnson engines 2 through 8 horsepower. What measurement should *X* be?

  Measurement X — ______________________________

Assignment Sheet 2

Figure 9: Mercury float-level adjustment

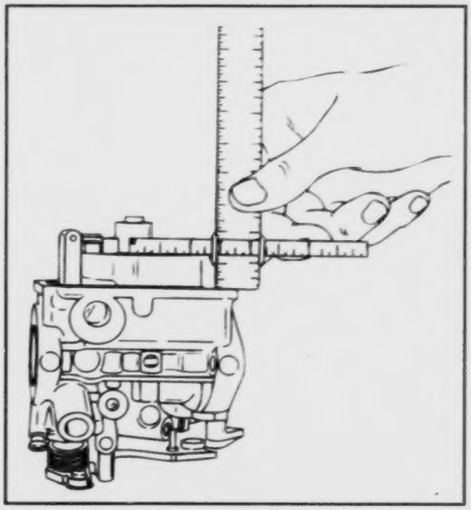

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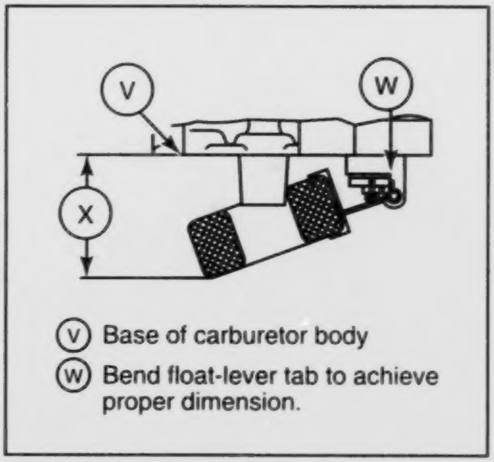
Figure 10: Johnson fuel-level adjustment


V
W
X
(V) Base of carburetor body
(W) Bend float-lever tab to achieve proper dimension.

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Assignment Sheet 2

6. For proper operation, the ignition timing, carburetor, and idle speed must be properly adjusted and synchronized. Answer the following questions for Mercury 40, 50, 55, and 60 engines.

   a. The timing light is placed on which spark-plug lead?

      Spark-plug lead — ______________________________

   b. When performing carburetor synchronization, what is the recommended clearance between the roller of the cam follower and the throttle cam?

      Recommended clearance — ______________________________

   c. What is the recommended free play in the throttle linkage?

      Free play — ______________________________

   d. What is the initial adjustment of the low-speed-mixture screws?

      Initial adjustment — ______________________________

   e. What is the recommended rpm idle setting?

      Rpm — ______________________________

Operation and Service of Engine-Support Systems
Unit 2

Assignment Sheet 3—Determine Outboard-Engine Tune-Up Specifications and Parts Requirements

Name ______________________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	______
Minimum of 85 percent of answers are correct.	______
Overall rating	______

Evaluator's comments ____

____

____

Introduction

For an engine to operate properly, it must be correctly tuned. Correct specifications and parts must be used to achieve a proper tune-up. Tune-ups represent a major portion of the work performed by outboard-engine technicians. Therefore, technicians must be capable of doing a proper tune-up, which includes determining the correct specifications and parts to use. In this assignment sheet, you will practice selecting parts and determining specifications for tune-ups on outboard engines that you are likely to service.

Exercise

Directions

In each of the following sections, Parts A through G, use the resources available in your facility to determine the part numbers and specifications.

In Question 1 of each section, provide the specifications requested. In Question 2 of each section, your instructor will fill out the engine information, and then you will provide the specifications requested.

Assignment Sheet 3

Part A 1. What is the point-gap setting for the following engines?

Note: Not all of the engines listed are available with breaker ignition systems. Write N/A for those that do not use breaker systems.

	Engine	Point-gap setting
a.	Chrysler 65 hp	
b.	Yamaha 8 hp	
c.	Mariner 175 hp	
d.	Mercury model 300	
e.	Evinrude 120 hp	

2. Your instructor will complete the "Engine" column in the table below. What is the point-gap setting for these engines?

	Engine	Point-gap setting
a.		
b.		
c.		
d.		
e.		

Part B 1. What is the recommended spark plug and spark-plug gap setting for each of the following engines?

	Engine	Spark plug	Gap setting
a.	Chrysler 8 hp		
b.	Johnson 40 hp		
c.	Mariner 200 hp		
d.	Suzuki DT115		
e.	Mercury in-line 6-cylinder		

Assignment Sheet 3

2. Your instructor will complete the "Engine" column in the table below. What is the recommended spark plug and spark-plug gap setting for these engines?

	Engine	Spark plug	Gap setting
a.			
b.			
c.			
d.			
e			

Part C

1. What is the recommended fuel float-level distance for each of the following engines?

	Engine	Float-level distance
a.	Chrysler 5 hp	
b.	Johnson 30 hp	
c.	Mariner 115 hp	
d.	Mercury 3.4 liter	
e.	Tanaka TOB-550	

2. Your instructor will complete the "Engine" column in the table below. What is the recommended fuel float-level distance for each of these engines?

	Engine	Float-level distance
a.		
b.		
c.		
d.		
e.		

Assignment Sheet 3

Part D

1. What is the recommended idle speed for each of the following engines?

	Engine	Idle speed
a.	Chrysler 8 hp	
b.	Evinrude 3-cylinder 70 hp	
c.	Mercury 7.5 hp	
d.	Suzuki DT140	
e.	Yamaha 30 hp	

2. Your instructor will complete the "Engine" column in the table below. What is the recommended idle speed for these engines?

	Engine	Idle speed
a.		
b.		
c.		
d.		
e.		

Part E

1. At what position is the ignition timing set for each of the following engines?

	Engine	Ignition timing
a.	Chrysler 60 hp	
b.	Johnson 8 hp	
c.	Mariner 25 hp	
d.	Mercury 300 hp	
e.	Suzuki DT30	

Assignment Sheet 3

2. Your instructor will complete the "Engine" column in the table below. At what position is the ignition timing set for these engines?

	Engine	Ignition timing
a.	____________	____________________
b.	____________	____________________
c.	____________	____________________
d.	____________	____________________
e.	____________	____________________

Part F

1. Using materials available in your facility, study the ignition systems used on the following engines. In the space provided, describe those ignition systems. Be sure to state the manufacturer's term for the ignition control module and other major components.

   a. Engine — Evinrude 70 horsepower, 4-stroke

   Ignition-system description — ____________________

   b. Engine — Mercury V-300

   Ignition-system description — ____________________

   c. Engine — Mercury 60 horsepower

   Ignition-system description — ____________________

Assignment Sheet 3

d. Engine — Mercury 9.9 horsepower

Ignition-system description — ______________________________

____

____

____

e. Engine — Johnson 8 horsepower

Ignition-system description — ______________________________

____

____

____

f. Engine — Evinrude 175 horsepower fuel-injected

Ignition-system description — ______________________________

____

____

____

2. Your instructor will complete the "Engine" blank in the following items. In the space provided, describe those ignition systems. Be sure to state the manufacturer's term for the ignition control module and other major components.

a. Engine — ____

Ignition-system description — ______________________________

____

____

____

b. Engine — ____

Ignition-system description — ______________________________

____

____

____

Assignment Sheet 3

c. Engine — ______________________

Ignition-system description — ______________________

____

____

____

d. Engine — ______________________

Ignition-system description — ______________________

____

____

____

e. Engine — ______________________

Ignition-system description — ______________________

____

____

____

Part G 1. For an Evinrude 115-horsepower engine with fuel injection, complete the following table by listing the meaning of the identified service codes.

	Code	Meaning
a.	14	______________
b.	23	______________
c.	34	______________
d.	55	______________
e.	83	______________

2. Your instructor will complete the "Code" column in the following table for the engine she or he will identify on the blank below. Complete the table by listing the meaning of the identified service codes.

Engine — ______________________________

	Code	Meaning
a.		
b.		
c.		
d.		
e.		

Operation and Service of Engine-Support Systems
Unit 2

Assignment Sheet 4—Interpret an Outboard-Engine Troubleshooting Chart

Name ______________________________ Date ________________

Evaluation criteria	**Rating**
Directions have been followed.	_______
Minimum of 85 percent of answers are correct.	_______
Overall rating	_______

Evaluator's comments ____

____

____

Introduction

Troubleshooting is a systematic approach to determining the cause of engine-performance problems. Many manufacturers provide charts and diagrams to assist technicians in the troubleshooting process. These charts have various formats but generally list symptoms, probable causes, and recommended corrective actions. In some cases, the troubleshooting chart will guide the technician through a series of alternative choices to narrow down the probable cause to the most likely possibility. In this assignment sheet, you will practice using a troubleshooting chart to diagnose problems.

Exercise

Directions

Using the resources available in your facility and the troubleshooting chart included in this assignment sheet, answer each of the following questions. Write an "X" on the blank before the correct answer with each question.

1. An engine will not start and backfires in the lower unit. Which of the following is **not** a likely cause of the problem?

    _______ a. Spark-plug wires reversed

    _______ b. Timing out of adjustment

    _______ c. Flywheel-key sheared

    _______ d. Reed valves seated

Assignment Sheet 4

2. An engine runs rough and smokes excessively. Which of the following is a probable cause?

_______ a. Carburetor set too lean

_______ b. Not enough oil mixed with the fuel

_______ c. Float level is too high

_______ d. Punctured fuel-pump diaphragm

3. An engine misses at low speed. Technician A suggests that the problem could be that the spark plugs are dirty or improperly gapped. Technician B suggests that the coil or condenser may be weak. Who is correct?

_______ a. Technician A

_______ b. Technician B

_______ c. Both Technician A and Technician B

_______ d. Neither Technician A nor Technician B

4. Which of the following is **not** likely to be a problem that results from a lean carburetor setting?

_______ a. Engine coughs, spits, and slows

_______ b. Engine vibrates excessively

_______ c. Engine idles well, but there is no acceleration when put to full power

_______ d. Engine not idling smoothly or slowly enough

5. An engine runs well for a short period of time and then slows and stops. Technician A says that the spark-plug heat range may be too high. Technician B says that the spark-plug heat range may be too low. Who is correct?

_______ a. Technician A

_______ b. Technician B

_______ c. Both Technician A and Technician B

_______ d. Neither Technician A nor Technician B

Assignment Sheet 4

Troublshooting Chart

The following chart lists 25 engine-performance problems and their probable causes.

1. **Starter rope does not return**
   - Recoil spring broken or binding
   - Starter housing bent
   - Loose or missing parts

2. **Manual starter clatters**
   - Friction spring bent or burred
   - Starter housing bent
   - Excess grease on pawls or spring
   - Dry starter sprindle

3. **Electric starter is inoperative**
   - Loose or corroded connections or ground
   - Starting-circuit safety switch open, or out of adjustment
   - Under capacity or weak battery or corroded battery terminals
   - Faulty starter solenoid
   - Moisture in electric starter motor
   - Broken or worn brushes in starter motor
   - Faulty fields
   - Faulty armature
   - Broken wire in harness or connector
   - Faulty starter key or pushbutton switch
   - Worn or frayed insulation

4. **Electric starter does not engage but solenoid clicks**
   - Loose or corroded connections or ground
   - Weak battery
   - Faulty starter solenoid
   - Broken wire in electric harness
   - Loose or stripped post on starter motor
   - See steps in number 3

5. **Engine is hard to start or won't start**
   - Empty gas tank
   - Gas-tank air vent not open
   - Fuel lines kinked or severely pinched
   - Water or dirt in fuel system
   - Clogged fuel filter or screens
   - Engine not being choked to start
   - Engine not primed—pump primer system
   - Carburetor adjustments too lean (not allowing enough fuel to start engine)
   - Timing and synchronizing out of adjustment
   - Manual choke linkage bent—auto choke out of adjustment
   - Spark plugs improperly gapped, dirty, or broken
   - Fuel-tank primer inoperative (pressurized system)
   - Ignition points improperly gapped, burned, or dirty
   - Loose, broken wire or frayed insulation in electrical system
   - Reed valves not seating or stuck shut
   - Weak coil or condenser
   - Faulty gaskets
   - Cracked distributor cap or rotor
   - Loose fuel connector
   - Electronic-ignition component malfunction

5. **Engine is hard to start or won't start** (cont.)
   - Faulty fuel pump
   - Dirty or inoperative fuel injectors

6. **Low-speed miss or engine won't idle smoothly and slowly enough**
   - Too much oil – too little oil
   - Timing and synchronizing out of adjustment
   - Carburetor idle adjustment (mixture lean or rich)
   - Ignition points improper (gap, worn or fouled)
   - Weak coil or condenser
   - Loose or broken ignition wires
   - Loose or worn magneto plate
   - Spark plugs (improper gap or dirty)
   - Head gasket, reed-plate gasket (blown or leaking)
   - Reed valve standing open or stuck shut
   - Plugged crankcase bleeder, check valves, or lines
   - Leaking crankcase halves
   - Leaking crankcase seals (top or bottom)
   - Exhaust gases returning through intake manifold
   - Electronic-ignition component malfunction

7. **High-speed miss or intermittent spark**
   - Spark plugs improperly gapped or dirty
   - Loose, leaking, or broken ignition wires
   - Breaker points (improper gap or dirty; worn cam or cam follower)
   - Weak coil or condenser
   - Water in fuel
   - Leaking head gasket or exhaust-cover gasket
   - Spark-plug heat range incorrect
   - Engine improperly timed
   - Carbon or fouled combustion chambers
   - Magneto or distributor poorly grounded
   - Distributor oiler wick bad
   - Electronic-ignition component malfunction

8. **Engine coughs, spits, slows**
   - Idle or high-speed needles set too lean
   - Carburetor not synchronized
   - Leaking gaskets in induction system
   - Obstructed fuel passages
   - Float level set too low
   - Improperly seated or broken reeds
   - Fuel-pump pressure line ruptured
   - Fuel pump (punctured diaphragm), check valves stuck open or closed, fuel lines leak
   - Poor fuel-tank pressure (pressurized system)
   - Worn or leaking fuel connector

9. **Engine vibrates excessively or runs rough and smokes**
   - Idle or high-speed needles set too rich
   - Too much oil mixed with gas
   - Carburetor not synchronized with ignition properly
   - Choke not opening properly
   - Float level too high
   - Air passage to carburetor obstructed

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Assignment Sheet 4

Troublshooting Chart

(continued)

9. **Engine vibrates excessively or runs rough and smokes** (cont.)
   - Bleeder valves or passages plugged
   - Transom bracket clamps loose on transom
   - Propeller out of balance
   - Broken engine mount
   - Exhaust gases getting inside motor cover
   - Poor ignition – see number 7

10. **Engine runs well, idles well for a short period, then slows down and stops**
    - Weeds or other debris on lower unit or propeller
    - Insufficient cooling water
    - Carburetor, fuel pump, filter, or screens dirty
    - Bleeder valves or passages plugged
    - Lower-unit bind (lack of lubrication or bent)
    - Gas-tank air vent not open
    - Not enough oil in gas
    - Combustion chambers and spark plugs fouled, causing preignition
    - Spark-plug heat range too high or too low
    - Wrong propeller (preignition)
    - Slow-speed adjustment too rich or too lean

11. **Engine won't start, kicks back, backfires into lower unit**
    - Spark-plug wires reversed
    - Flywheel key sheared
    - Distributor-belt timing off (magneto or battery ignition)
    - Timing and synchronizing out of adjustment
    - Reed valves not seating or broken

12. **Engine will not accelerate, low top rpm**
    - Improper carburetor adjustments
    - Improper timing and synchronization
    - Spark plugs (improper gap or dirty)
    - Ignition-system malfunction
    - Faulty coil or condenser
    - Loose, leaking, or broken ignition wires
    - Reed valves not properly seated or broken
    - Blown head or exhaust-cover gasket
    - Weeds on lower unit or propeller
    - Incorrect propeller
    - Insufficient oil in gas
    - Insufficient oil in lower unit
    - Fuel restrictions
    - Scored cylinder – stuck rings
    - Marine growth, hooks, rockers, or change in load of boat
    - Sticky magneto plate
    - Carbon buildup on piston head at deflector

13. **Engine will not accelerate, idles well but when put to full power dies down**
    - High- or low-speed needle set too lean
    - Dirt or packing behind needles and seats
    - High-speed nozzle obstructed
    - Float level too low
    - Choke partly closed
    - Improper timing and synchronization

13. **Engine will not accelerate, idles well but when put to full power dies down** (cont.)
    - Fuel lines or passages obstructed
    - Fuel filter obstructed
    - Not enough oil in gas
    - Breaker points improperly gapped or dirty
    - Bent gearcase or exhaust tube

14. **Engine runs at high speed only by using hand primer**
    - Carburetor adjustments
    - Dirt or packing behind needles and seat
    - Fuel lines or passages obstructed
    - Fuel line leaks
    - Fuel pump not supplying enough fuel
    - Float level too low
    - Fuel filter obstructed
    - Fuel tank or connector at fault

15. **Engine has no power under heavy load**
    - Wrong propeller
    - Weeds or other debris on lower unit or propeller
    - Breaker points improperly gapped or dirty
    - Stator plate loose
    - Ignition timing over advanced or late
    - Faulty carburetion and/or faulty ignition
    - Propeller hub slips
    - Scored cylinders or rings stuck
    - Carbon buildup on piston head at deflector

16. **Engine cranks over extremely easily on one or more cylinders**
    - Low compression
      - Worn or broken rings
      - Scored cylinder or pistons
      - Blown head gasket
      - Loose spark plugs
      - Loose head bolts
      - Crankcase halves improperly sealed
      - Burned piston

17. **Engine won't crank over**
    - Manual-start lock improperly adjusted
    - Pistons rusted to cylinder wall
    - Lower-unit gears, prop shaft rusted or broken
    - Broken connecting rod, crankshaft, or driveshaft
    - Coil heels binding on flywheel
    - Engine improperly assembled

18. **Engine overheats**
    - Engine not deep enough in water
    - Not enough oil in gas or improperly mixed
    - Bad thermostat
    - Seals or gaskets (burned, cracked, or broken)
    - Impeller key not in place or broken
    - Plugged water inlet, outlet, or cavity
    - Obstruction in water passages
    - Broken, pinched, or leaking water lines
    - Improper ignition timing
    - Engine not assembled properly

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Assignment Sheet 4

Troublshooting Chart

(continued)

18. Engine overheats (cont.)
- Shortened heat-light wiring
- Bad water-pump impeller, plate, housing, or seal

19. Engine stops suddenly, freezes up
- No oil in gas, or no gas
- Insufficient cooling water
- No lubricant in gearcase
- Rusted cylinder or crankshaft
- Bent or broken rod, crankshaft, drive-shaft, propeller shaft, stuck piston
- Bad water pump or plugged water passages

20. Engine knocks excessively
- Too much or not enough oil in gas
- Worn or loose bearings, pistons, rods, or wrists pins
- Over advanced ignition timing
- Carbon in combustion chambers and exhaust ports
- Manual starter not centered
- Flywheel nut loose
- Flywheel hitting coil heels
- Bent shift rod (vibrating against exhaust tube)
- Loose assemblies, bolts, or screws

21. Alternator will not charge
- Battery condition
- Connections loose or dirty
- Drive belt loose or broken
- Faulty regulator or cutout relay
- Field fuse or fusbile wire in regulator blown
- Open alternator windings
- Worn or sticking brushes and/or slip rings
- Faulty rectifier diodes
- Faulty ammeter

22. Low alternator output and a low battery
- High resistance at battery terminals
- High resistance in charging circuit
- Faulty ammeter
- Low regulator setting
- Faulty rectifier diodes
- Faulty alternator

23. Excessive battery charging
- Regulator set too high
- Regulator contacts stuck
- Regulator voltage winding open
- Regulator improperly grounded
- High resistance in field coil
- Regulator improperly mounted

24. Excessive fuel consumption
- Hole in fuel-pump diaphragm
- Deteriorated carburetor gaskets
- Altered or wrong fixed jets
- Jets improperly adjusted
- Carburetor casting porous
- Float level too high
- Loose distributor pulley

25. Shifter dog jumps
- Worn shifter dog or worn gear dogs
- Worn linkage
- Remote-control adjustment
- Gearcase loose or sprung
- Exhaust housing bent
- Linkage out of adjustment

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 1—Fuel, Start, Operate, and Shut Down Outboard Engines

Introduction

This job sheet covers the procedure for fueling, starting, operating, and shutting down outboard engines. These procedures will vary depending on the type of engine used and its engine-support systems. For example, an outboard engine may use a manual recoil starter or an electric starter system and may have direct manual control of the engine or electrical or mechanical remote control. All of these and other features will affect the procedures for fueling, starting, operating, and shutting down outboard engines. These procedures may include

- Mix fuel and fill fuel reservoir
- Prime or choke engine
- Start engine
- Set throttle to warm-up position
- Adjust throttle for desired operation
- Shut off engine

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of fueling, starting, operating, and shutting down outboard engines and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 1

Worksheet—Fuel, Start, Operate, and Shut Down Outboard Engines

Name ____________________ Attempt number ________

Date ____________________

Part A: Pre-performance check

Job ____________________

- Complete the following information concerning the assigned equipment.

  Equipment model/type and code ____________________

- List references used regarding fueling, starting, operating, and shutting down the engine.

  Service-manual title ____________________

  Section/page number of procedure ____________________

- Describe type of fuel to be used and list additives or oil mixture and ratio.

- Describe starting procedure.

- Describe shut-down procedure.

Instructor's signature ____________________

Job Sheet 1

Worksheet—Fuel, Start, Operate, and Shut Down Outboard Engines

---

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Controls used correctly.	______
Safety precautions observed.	______
Operation within specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 2—Perform Routine Maintenance on Fuel Systems

Introduction

This job sheet covers the routine maintenance associated with fuel systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Inspect components, including hoses, filters, pump, valves, fuel injectors, etc.
- Clean carburetor and fuel-intake valves
- Check and adjust fuel pressure
- Test enrichment system
- Adjust float height
- Replace fuel filter

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of performing routine maintenance on fuel systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 2

Worksheet—Perform Routine Maintenance on Fuel Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 2

Worksheet—Perform Routine Maintenance on Fuel Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	
Procedures completed correctly.	
Proper tools used correctly.	
Safety precautions observed.	
Service meets specifications.	
Clean-up and follow-up actions adequate.	
Overall rating	

Evaluator's comments ______________________________

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 3—Repair Fuel Systems

Introduction

This job sheet covers the repair procedures associated with fuel systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace components, including floats, injectors, pumps, hoses, etc.
- Overhaul components, including carburetors, etc.
- Perform adjustments to return system to original operating specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of repairing fuel systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 3

Worksheet—Repair Fuel Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 3

Worksheet—Repair Fuel Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 4—Perform Routine Maintenance on Lubrication Systems

Introduction

This job sheet covers the routine maintenance associated with lubrication systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Mix oil with fuel
- Inspect components, including lines, pump, tank, etc.
- Test oil-pump output
- Adjust oil flow
- Adjust pump subsystem, including screens, gears, etc.
- Change oil and filter

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of performing routine maintenance on lubrication systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 4

Worksheet—Perform Routine Maintenance on Lubrication Systems

Name ______________________ Attempt number ________

Date ______________________

Part A: **Pre-performance check**

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 4

Worksheet—Perform Routine Maintenance on Lubrication Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 5—Repair Lubrication Systems

Introduction

This job sheet covers the repair procedures associated with lubrication systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace components, including tank, pump, hoses, etc.
- Overhaul subsystems, including pump, etc.
- Perform adjustments to return system to original operating specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of repairing lubrication systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 5

Worksheet—Repair Lubrication Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 5

Worksheet—Repair Lubrication Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

# Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 6—Perform Routine Maintenance on Cooling Systems

Introduction This job sheet covers the routine maintenance associated with cooling systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes as well as the type of equipment drive, the general tasks that may be performed under this procedure include

- Inspect components, including water tube, head for water-jacket leaks, pump, seals and gaskets, etc.
- Check for leaks
- Clean system, including inlet port
- Test thermostat

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of performing routine maintenance on cooling systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 6

Worksheet—Perform Routine Maintenance on Cooling Systems

Name ______________________ Attempt number ________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 6

Worksheet—Perform Routine Maintenance on Cooling Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	________
Procedures completed correctly.	________
Proper tools used correctly.	________
Safety precautions observed.	________
Service meets specifications.	________
Clean-up and follow-up actions adequate.	________
Overall rating	________

Evaluator's comments ____

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Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 7—Repair Cooling Systems

Introduction

This job sheet covers the repair procedures associated with cooling systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace components, including impeller, thermostats, head gasket, etc.
- Overhaul subsystems, including pumps, water tubes, etc.
- Perform adjustments to return system to original operating specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of repairing cooling systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 7

Worksheet—Repair Cooling Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 7

Worksheet—Repair Cooling Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 8—Perform Routine Maintenance on Ignition Systems

Introduction

This job sheet covers the routine maintenance associated with ignition systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Inspect mechanical components
- Inspect electrical components
- Test electrical characteristics, including charge-coil resistance and output, sensor-coil resistance and output, primary- and secondary-circuit resistance and output, etc.
- Clean and gap spark plug
- Adjust breaker gap

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of performing routine maintenance on ignition systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 8

Worksheet—Perform Routine Maintenance on Ignition Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 8

Worksheet—Perform Routine Maintenance on Ignition Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	
Procedures completed correctly.	
Proper tools used correctly.	
Safety precautions observed.	
Service meets specifications.	
Clean-up and follow-up actions adequate.	
Overall rating	

Evaluator's comments ______________________________

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 9—Repair Ignition Systems

Introduction

This job sheet covers the repair procedures associated with ignition systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace components, including spark plugs, electronic components, coils, points, etc.
- Perform adjustments to return system to original operating specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of repairing ignition systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 9

Worksheet—Repair Ignition Systems

Name ________________________ Attempt number ________

Date ________________________

Part A: **Pre-performance check**

Job ________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ________________________

  Equipment model/type and code ________________________

  ____

- Complete the following service-manual information.

  Service-manual title ________________________

  Section/page number of procedure ________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ________________________

Job Sheet 9

Worksheet—Repair Ignition Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	
Procedures completed correctly.	
Proper tools used correctly.	
Safety precautions observed.	
Service meets specifications.	
Clean-up and follow-up actions adequate.	
Overall rating	

Evaluator's comments ______________________________

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 10—Perform Routine Maintenance on Starting Systems

Introduction

This job sheet covers the routine maintenance associated with starting systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Inspect rope, spring, and other mechanical components
- Adjust preload on rope starter
- Inspect mechanical components
- Inspect electrical components
- Test electrical characteristics, including battery load, starter draw, and voltage drop
- Test battery specific gravity
- Clean and inspect starter brushes and armature
- Test solenoids, voltage regulators, and switches, including safety switches
- Charge and service battery

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of performing routine maintenance on starting systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 10

Worksheet—Perform Routine Maintenance on Starting Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 10

Worksheet—Perform Routine Maintenance on Starting Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

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Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 11—Repair Starting Systems

Introduction

This job sheet covers the repair procedures associated with starting systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace components, including ropes, springs, handles, battery, starter motor, wiring, switch, etc.
- Overhaul starting system, including clutch subsystems, brushes, and windings
- Perform adjustments to return system to original operating specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of repairing starting systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 11

Worksheet—Repair Starting Systems

Name ______________________ Attempt number ________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 11

Worksheet—Repair Starting Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

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____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 12—Perform Routine Maintenance on Charging Systems

Introduction

This job sheet covers the routine maintenance associated with charging systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Inspect mechanical components
- Inspect electrical components
- Test electrical characteristics, including stator-coil resistance, output, the rectifier/regulator assembly, etc.
- Adjust belt tension
- Adjust component alignment and spacing

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of performing routine maintenance on charging systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 12

Worksheet—Perform Routine Maintenance on Charging Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ____

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 12

Worksheet—Perform Routine Maintenance on Charging Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

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____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 13—Repair Charging Systems

Introduction

This job sheet covers the repair procedures associated with charging systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace components, including flywheel alternator strators, wiring, etc.
- Overhaul subsystems, including alternators, stators, switches, etc.
- Perform adjustments to return system to original operating specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of repairing charging systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 13

Worksheet—Repair Charging Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

Equipment brand ______________________________

Equipment model/type and code ______________________________

____

- Complete the following service-manual information.

Service-manual title ______________________________

Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 13

Worksheet—Repair Charging Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ______________________________

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____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 14—Perform Minor Tune-Ups

Introduction

This job sheet covers the procedures associated with performing minor tune-ups. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Adjust timing
- Replace spark plugs and filters
- Change oil and lubricants
- Adjust fuel flow
- Inspect exhaust ports and clean as necessary

Note: There is no standard definition of a minor tune-up, so the exact tasks will vary with different organizations and for the design and configuration of the engine. Discuss the required procedures for a particular engine assignment with your instructor in Step 5 of this job sheet.

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of performing minor tune-ups and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

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Job Sheet 14

Worksheet—Perform Minor Tune-Ups

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 14

Worksheet—Perform Minor Tune-Ups

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 15—Perform Major Tune-Ups

Introduction

This job sheet covers the procedures associated with performing major tune-ups. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace or adjust ignition components
- Replace or adjust fuel-system components
- Replace or adjust cooling-system components
- Replace or adjust timing components
- Inspect exhaust ports and clean as necessary

Note: There is no standard definition of a major tune-up, so the exact tasks will vary with different organizations and for the design and configuration of the engine. Discuss the required procedures for a particular assignment with your instructor in Step 5 of this job sheet.

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.
2. Watch your instructor's demonstration of performing major tune-ups and any supporting media provided by your instructor.
3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.
4. Ask your instructor to provide you with an outboard engine.
5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.
6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.
7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 15

Worksheet—Perform Major Tune-Ups

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 15

Worksheet—Perform Major Tune-Ups

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

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____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 16—Troubleshoot Failure-to-Start in Outboard Engines

Introduction This job sheet covers the procedures associated with troubleshooting failure-to-start in outboard engines. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. The procedure will consist of applying troubleshooting procedures to determine the cause of the failure-to-start condition and correcting those problems. If you need additional studies in troubleshooting procedures, see MAVCC's *Power Product Equipment Technician: Engine Systems and Service,* Unit 10, "Troubleshooting."

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of troubleshooting failure-to-start conditions and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 16

Worksheet—Troubleshoot Failure-to-Start in Outboard Engines

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 16

Worksheet—Troubleshoot Failure-to-Start in Outboard Engines

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Engine-Support Systems
Unit 2

Job Sheet 17—Perform Failure Analysis on Outboard Engines

Introduction This job sheet covers the procedures associated with performing failure analysis on outboard engines. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. The procedure will consist of applying the failure-analysis process. If you need additional studies in the failure-analysis process, see MAVCC's *Power Product Equipment Technician: Engine Systems and Service,* Unit 12, "Failure Analysis."

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of performing failure analysis and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 17

Worksheet—Perform Failure Analysis on Outboard Engines

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 17

Worksheet—Perform Failure Analysis on Outboard Engines

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

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____

Operation and Service of Power-Output Systems
Unit 3

Objective Sheet

Unit objective

After completing this unit, the student should be able to identify the types of power-output systems used in outboard engines and perform routine service procedures on such systems. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific objectives

After completing this unit, the student should be able to

1. Describe the typical power-output systems used in outboard engines.
2. Match the major components of power-output systems to their correct functions.
3. List the design features used to classify power-output systems.
4. Complete statements about the principles of operation of mechanical-shifting power-output systems.
5. Match the major components of outboard-engine propeller assemblies to their correct functions.
6. List the materials used in the manufacture of outboard-engine propellers.
7. Describe the principles of propeller rotation and counter-rotation.
8. List the design features used to classify propeller hubs.
9. Define types of propeller defects.
10. Complete guidelines for sending a propeller to a repair facility.
11. State safety rules for servicing power-output systems.
12. List the probable causes of poor boat performance related to power-output systems.
13. List methods used to compensate for walking.
14. Determine parts and specifications for power-output systems. (Assignment Sheet 1)
15. Interpret a power-output-system troubleshooting chart. (Assignment Sheet 2)
16. Calculate gear ratios. (Assignment Sheet 3)
17. Determine correct propeller characteristics for specific applications. (Assignment Sheet 4)
18. Perform routine maintenance on power-output systems. (Job Sheet 1)

Objective Sheet

19. Repair power-output systems. (Job Sheet 2)
20. Remove and replace propellers. (Job Sheet 3)
21. Check rpm on propellers. (Job Sheet 4)
22. Perform failure analysis on power-output-system components. (Job Sheet 5)

Operation and Service of Power-Output Systems
Unit 3

Information Sheet

1. **Description of the typical power-output systems used in outboard engines**

   - The purpose of an outboard engine is to apply the power produced by the engine in such a way that work is accomplished. In the case of an outboard engine, the work to be done is the movement of a boat across water. Therefore, the engine output must be directed in such a way that power is applied to moving the boat.

   - The transfer of power is done through the drive train, which consists of the drive shaft in the midsection and the gearcase and propeller assembly in the lower unit (see items 1, 2, and 3 in Figure 1 on the next page).

   - Some designs will also include mechanisms for shifting the direction or speed of propeller rotation or the angle of the propeller blades.

2. **Major components of power-output systems and their functions** (see Figure 1 on the next page)

   - **Housing**—Protects the power-output-system components and determines the depth of the propeller

     Note: Housings are manufactured in lengths that will provide the standard transom heights of 15 and 20 inches (38 and 51 cm). Many engines offer midsection or motor-leg extensions to increase a standard housing to the longer transom height. These kits include extensions for the housing, drive shaft, shift rod, water tube, and other components.

   - **Drive shaft**—Transfers the power from the engine to the lower unit

   - **Shift rod**—Transfers the mechanical force from the shift control to engage the forward or reverse gears with the propeller shaft

   - **Antiventilation plate**—Separates the submerged and above-water portions of the engine

     Note: The antiventilation plate is designed to ride just below the surface of the water at an angle approximately parallel to the lower planing surface of the boat. Its primary purpose is to control the disturbance caused by the propeller's turning. If water is pulled from too near the surface, air will be captured in the flow and reduce the efficiency of the propeller. If the water stream produced by the propeller is allowed to spread too quickly, efficiency is also reduced.

   - **Trim tab**—Offsets the flow of water produced by the propeller to overcome torque forces that would cause the boat to veer to one side

     Note: The trim tab is manually adjusted to offset the propeller forces. Engine torque causes some sideways motion of the boat.

   - **Exhaust port**—Allows water from the cooling system and the engine exhaust gases to exit the engine

     Note: While the primary function of the exhaust port is to allow the exit of exhaust gases and heated water from the cooling system, many engine designs incorporate the exhaust port into the trim tab so that the force of the escaping gases and water is added to the thrust of the power-output system.

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- **Gearcase**—Houses the gears that transmit power from the drive shaft to the propeller

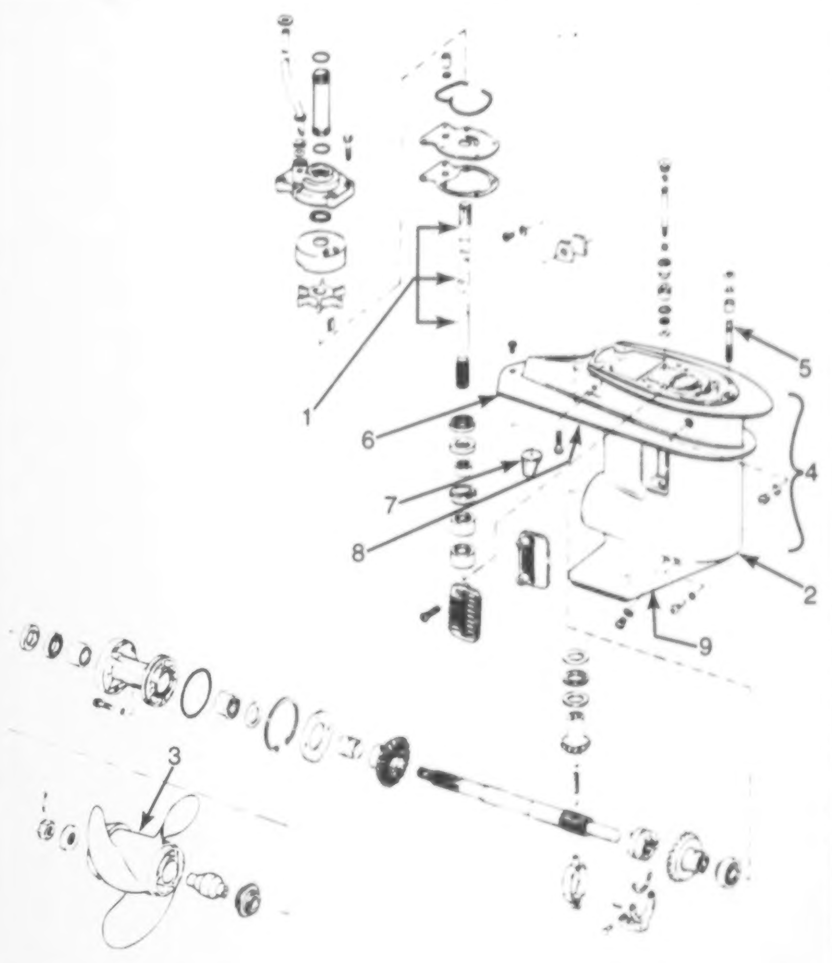
  Note: Some outboard engines have a single gear ratio so that the torque output for any engine speed is essentially the same. Others have variable gears that can be changed for high- or low-speed operation.

- **Propeller**—Moves water from one side of its blades to the other to create movement of the boat

  Note: Propellers are often neglected as a service item; however, for good engine efficiency and boat performance, it is critical that the propeller be properly matched to the boat and engine, that it be properly balanced and installed, and that it be free of damage and distortion.

- **Skeg**—Improves steering, helps provide even water flow past the propeller, and protects the propeller

Figure 1: Major components of power-output systems



1. Drive shaft
2. Gearcase
3. Propeller assembly
4. Housing
5. Shift rod
6. Antiventilation plate
7. Trim tab
8. Exhaust port
9. Skeg

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3. **Design features used to classify power-output systems**

Note: There are two basic types of power-output-system designs. The simpler design merely transfers power from the engine and redirects it along the propeller assembly to drive the boat forward. There is no range of gears or means of reversing the direction of rotation. The more-complex design allows the operator to shift the gearcase between forward and reverse rotation, often with a neutral position in which the propeller shaft is not engaged.

- **Nonshifting**
- **Mechanical shifting**

4. **Principles of operation of mechanical-shifting power-output systems** (see Figure 1 on page 154)

- **The pinion gear of the drive shaft meshes with gears in the gearcase.**

  Note: The drive shaft is basically an extension of the engine crankshaft. The lower end of the drive shaft terminates in the gearcase, where the pinion gear engages gearcase gears.

- **The gearcase changes the direction and often the gear ratio of the power transfer from the engine.**

  Note: The vertical input of the drive shaft is changed to a horizontal output to the propeller. The pinion gear and drive gear may have the same diameter and tooth patterns to create a 1:1 ratio, or the gear ratio may be other than 1:1.

- **The shift linkage positions the gears along the propeller shaft so that the forward gear, reverse gear, or neither gear is engaged with the propeller shaft.**

  Note: Most outboard engines use clutches that allow the forward and reverse gears to be engaged or disengaged. In some small engines, there is no reverse capability. The common type of clutch used is the jaw clutch (clutch dog). The clutch is often attached to the propeller shaft with a pin to integrate the two.

- **The drive gear engages the propeller shaft and causes it to rotate.**

  Note: The two common methods for meshing the drive gear and the propeller shaft are (1) through the jaw clutch or (2) through the use of splines in the hub of the drive gear.

- **The propeller shaft is supported by a bearing assembly to provide reduced friction and good alignment.**

  Note: The gearing assembly generally performs several functions. It not only supports the propeller shaft, but it also provides a watertight seal between the propeller and the gearcase.

- **The propeller is fastened to the propeller shaft and rotates as it turns.**

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- **A protective device usually joins the propeller to the shaft or the clutch to the shaft.**

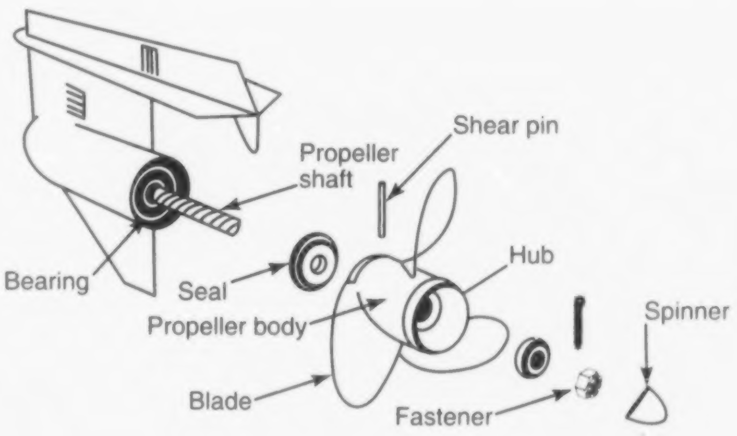
  Note: Because propeller blades are somewhat expensive and easily broken and because an impact to the propeller can cause damage to other lower-unit components, most outboard engines provide protection to the lower unit against damage due to the propeller's striking an object. This protection may be rubber cushions in the propeller hub, shear pins between the propeller and propeller shaft, shear pins between the clutch and propeller shaft, and other methods or combinations of methods.

5. **Major components of outboard-engine propeller assemblies and their functions** (see Figure 2)

Note: The components for specific designs of propeller assemblies will vary greatly with manufacturer, application, horsepower, and other factors. Basically, the parts must provide a means of transferring the power output from the engine and lower unit to a device that will move water. Additionally, there must be a way of keeping the water from getting into the lower unit and a means of fastening the propeller to the propeller shaft. Most designs also provide some method of reducing the damage that might occur if the propeller strikes a submerged object. The typical components for achieving these purposes are shown in Figure 2.

A propeller is simply a water pump. It moves water from one side of its blades to the other. More correctly, the propeller moves through the water by passing from one side of a section of water to the other, in much the same way that a screw moves through wood. The rotation of the propeller causes an area of lower pressure on the back side of the propeller, causing water to flow from the front side of the propeller blades to the area of lower pressure. This flow of water creates forward thrust as the propeller moves into the area of displaced water, thus pushing the boat ahead with its movement. The components of the propeller all serve to support this functioning.

Figure 2: Major components of propeller assemblies



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- **Spinner**—Covers the end of the propeller shaft

  Note: The spinner is generally a cone-shaped piece that fits over the end of the propeller shaft that projects through the propeller. Spinners are generally internally threaded so that they can be installed onto the end of the propeller shaft or a shaft housing. In those applications in which they are installed on the propeller shaft, spinners may serve as the fastener that prevents the propeller from sliding off the shaft. In other designs, they simply provide a decorative finish and offer some protection to the propeller. The cone shape helps to reduce disturbance of the flow of water through the propeller.

- **Fastener**—Keeps the propeller from sliding off the shaft

  Note: The propeller is normally installed by sliding it onto the end of the propeller shaft and is removed by sliding it off the shaft. There are several means of preventing the propeller from sliding off during normal operation. One of the most-common ways is to use a nut that is installed onto the threaded end of the propeller shaft, either as a standard nut or as a spinner. In some cases, slotted or castellated nuts are used. Other designs simply use a pin that passes through a hole in the propeller shaft. A cotter pin, for example, may be used with or without a washer and installed in a hole near the end of the shaft. In some cases, a shear pin is used both to hold the propeller onto the shaft and to join the motion of the two components.

- **Propeller body**—Supports the blades and forms a housing for the hub, shaft, bearings, and other components

  Note: Seldom does the propeller mount directly to the shaft, except in very small and generally inexpensive outboard engines. As the external rotating member, the propeller is the most likely engine component to be damaged during operation. Consequently, the propeller body must accommodate the hub or other components that form the physical link between the propeller and shaft.

- **Blade**—Moves water from one side of the propeller to the other

  Note: The blades are the most-important component in the overall design of a propeller. See Student Supplement 1, "Principles of Propeller Operation," for further discussion of propeller design and functioning.

- **Hub**—Mates the propeller to the shaft

  Note: Several designs are used to mate the propeller to the propeller shaft so that the propeller turns with the shaft. One of the most-common designs is to use a splined hub that meshes with splines on the propeller shaft. In this way, the hub and shaft are then essentially a single piece. In these designs, a component such as a shear pin is used to join the propeller to the hub. Some hubs are made of rubber to provide additional cushioning to protect the propeller.

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- **Shear pin**—Protects the propeller and lower unit in case the propeller strikes a submerged object

  Note: A shear pin is a device that is designed to break when subjected to pressure while the pressure is less than what is required to damage the propeller. In this way, if the propeller strikes a rock or log, the shear pin will break, allowing the propeller to stop rather than being damaged while the shaft continues turning. This also protects the lower-unit gears. While shear pins are a typical means of protecting the propeller and gearcase, not all engines use shear pins. Other engines use hubs or clutches that give way to excessive pressure, but most designs provide a means of protection. This cushioning provides some give to the propeller mounting and serves in place of a shear pin.

- **Seal**—Prevents water from entering the gearcase

  Note: The propeller must be exposed to water; however, that water must be kept from entering the gearcase. At some point between the propeller and the gearcase, there will be one or more seals. The seal is often installed in the end of the gearcase housing.

- **Bearing**—Supports the propeller shaft and reduces the friction from rotation

  Note: The propeller assembly will have one or more bearings. Typically, there is a bearing just inside the gearcase at the sealed end. The bearing supports the propeller shaft and also allows the shaft to rotate with less friction. Additional bearings may be contained in the hub or a special bearing housing to support the shaft as it extends through the propeller body.

- **Propeller shaft**—Transmits force from the engine to turn the propeller

6. Materials used in the manufacture of outboard-engine propellers

Note: A number of factors affect the choice of propeller material used. The size of the engine and boat application are major considerations. The size and weight of the boat, the conditions of its operating environment (weeds, obstacles, water depth, salt versus fresh water, etc.), how fast the boat is designed to travel, and similar factors affect the selection of propellers. The boat owner's preferences and budget also must be considered.

- **Cast aluminum**

  Note: Cast aluminum is the material most commonly used for outboard-engine propellers. The material is light, relatively inexpensive, rustproof, and resistant to electrolytic deterioration. Aluminum's drawbacks are that the material is not as strong as some other materials and, because it is somewhat brittle, is more likely to shatter or break in a collision or if handled roughly.

- **Stainless steel**

  Note: Stainless-steel propellers were once used primarily for racing boats and large, expensive watercraft with inboard or stern-drive engines. However, stainless-steel propellers are seeing increasing popularity with outboard units. While stainless-steel propellers cost more than cast aluminum and are heavier, they are corrosion- and rust-resistant, show little distortion at high torque, and are better candidates for repair if damaged.

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- **Plastic**

  Note: Though some trolling engines of 3 horsepower or less and similar small engines use a plastic propeller as their primary propeller, most engines use a plastic propeller only as an emergency-replacement propeller. Many boaters carry a spare plastic propeller because this secondary propeller is inexpensive and can be installed to permit the boat to get back to shore if the primary propeller is damaged.

- **Cast bronze**

  Note: Cast-bronze propellers have been a popular choice for large boats for many years. They have recently gained some popularity for outboard-engine applications because they offer many of the advantages of stainless-steel propellers at a lower cost.

7. Description of the principles of propeller rotation and counter-rotation

- Blades are set at an angle on the propeller.
- The propeller turns in such a way that water flows from the leading edge of the blade to the trailing edge of the blade with increasing speed.
- The normal rotation of the propeller is such that water will flow from the front of the blade to the rear of the blade.
- In North America, normal rotation of the propeller is clockwise when the mounted engine is viewed from behind the stern of the boat.
- Counter-rotation is a counterclockwise rotation of the propeller—rotation in the opposite direction of normal rotation.

  Note: Boats that use two engines generally have one that rotates clockwise and one that rotates counterclockwise, usually with the rotation being toward the outside of the boat. This is the use of counter-rotation to offset the torque of a single engine. The flow of water past the propeller is the same in both types of propellers.

8. Design features used to classify propeller hubs

- **Construction material used**—Metal (aluminum, steel, and brass) or plastic (nylon, rubber, and vinyl)

  Note: Hubs made of the softer materials listed above are generally of the fixed design and are used to provide collision protection.

- **Hub configuration**—Fixed or dynamic

  Note: A fixed hub is solid and meshes rigidly with the propeller shaft and the propeller. A dynamic hub has rotating parts, such as bearings, that support the propeller shaft.

9. Types of propeller defects and their definitions

- **Warped blades**—Propeller blades with a blade angle that is no longer at the angle of manufacture; a defect caused by the twisting of the blade material

  Note: The common causes of warped blades are exposure to heat or chemicals or sudden changes in temperature, such as putting a sun-heated blade into very cold water.

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- **Worn blades**—Propeller blades with a reduced diameter or thrust area due to the friction created as the blades rotate through the water

  Note: Even clean water can wear the surfaces of propeller blades; water that contains suspended dirt or sand will quickly wear the blade surfaces. Also, because the outer edges of a propeller's blades turn faster than the inside portions, the outer edges wear especially fast.

- **Nicked blades**—Propeller blades with small pieces broken off the blade edges

  Note: When boating in shallow waters, operators often run the boat into obstacles such as sandbars, stumps, and rocks that damage the propeller blades. However, even when boats are operated in deep water, floating logs, wildlife, equipment suspended over the side of the boat, and other objects can collide with and damage the propeller blades.

- **Blades with stress fractures**—Propeller blades with small, nearly invisible cracks in the blade material or at the joints where the blades join the hub

  Note: Stress fractures can occur whenever there is an impact to the propeller blades. While such impacts may be the result of the propeller's striking an object in the water, a common cause is mishandling of the propeller. The technician should never hit a propeller with a metal or hard-plastic hammer, and if the technician accidentally drops a propeller, he or she should carefully inspect the blades for cracks and fractures.

- **Broken blades**—Propeller blades with large pieces broken off

- **Missing blades**—Propeller with blades that have broken off

- **Bent blades**—Propeller blades with a blade angle no longer at the angle of manufacture; a defect caused by the lateral bending of the blade material

- **Corroded blades**—Propeller blades with pitting or crusty deposits as a result of the chemical action of oxygen, water, and acids

  Note: Rust and other forms of oxidation and the chemical action of acids on propeller blades can cause them to break apart.

- **Electrolytic deterioration**—Propeller blades with pitting, discoloration, flaking metal, or other symptoms of the excessive buildup of electrical charge and the results of exposure to acids

  Note: When dissimilar metals are placed together in the presence of an acid, electrical flow occurs. This is the principle of a lead/acid battery. This principle also applies when boats and metal propellers are placed in water because the water in various bodies of water—especially saltwater—is at least slightly acidic.

- **Worn propeller hub**—Propeller hub with an overly large bore or splines, allowing play in the propeller as it rotates

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10. Guidelines for sending a propeller to a repair facility

Note: Most power product equipment facilities do not have the capability to overhaul worn or damaged propellers. However, in some types of defects, facilities exist with the skills to make propeller repairs. When this option is available, the challenge for the technician becomes one of ensuring that the propeller can be delivered to the repair facility without suffering additional damage.

- **Ensure that the propeller is properly identified so that it can be matched to the correct boat when it is returned.**

- **Identify the known defects so that the repair facility will be sure to correct those defects during the repair process.**

  Note: Reputable repair facilities will evaluate the propeller to determine the repairability of the component and the repair requirements. If the propeller is beyond repair, they will recommend that it be scrapped. They may also identify and recommend additional repair procedures for propellers that are repairable.

- **Use a facility that can be trusted to give an honest evaluation of the propeller condition and that can do quality repairs.**

  Note: Most repair facilities will provide honest evaluations and do good work. However, the facility used must be familiar with the type of propeller and the processes and materials used in its manufacture. The facility must also be able to do those repair procedures that can return a propeller to a near-new condition and not undertake any procedures that are not helpful or not recommended by the propeller manufacturer. Finally, the facility should do only the work that is necessary and charge only for work done.

- **Have the facility commit to a return date.**

- **Coordinate the return date, cost, and processes to be performed with the customer and get the customer to approve the work.**

  Note: When quoting costs, be sure to include taxes, shipping expenses, handling charges for your facility, and other costs that the customer will be required to assume.

- **Pack the propeller in such a way that it will not receive additional damage during shipping and handling.**

- **Use a reputable shipping agent.**

- **Follow up with the repair facility to ensure that the work is proceeding, to determine whether additional processes are necessary, and to determine that the return date is still valid.**

- **Inspect the propeller upon return from the facility to ensure the quality of work, and notify the customer of the results of your inspection.**

  Note: It is quite likely that your facility will not be able to verify the quality of all repair work done. However, a poorly cleaned propeller, uneven taper in the blades, uneven depths of splines, visible weld joints, out-of-balance conditions, and other signs may be apparent to indicate that the quality of the repair is questionable.

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11. Safety rules for servicing power-output systems

Note: The output of the engine drives the propeller. This transfer of power goes through the lower unit. This use of power presents dangers to technicians who work around operating power-output systems. Additionally, while propellers do not possess sharpened blades, they can cause injury if dropped or broken. Always follow these rules to prevent personal injury or equipment damage during power-output-system service.

- **Do not operate the engine without the lower unit's being submerged.**

  Note: Outboard engines are designed to be operated in water. The cooling-system intake is in the lower unit and a source of coolant must be available. Many engines route their exhaust gases into the water. Air offers less resistance than water, meaning that the danger of overspeed is greater. Some manufacturers offer cooling-intake enclosures, sometimes referred to as *muffs*, that provide water through a hose connection to the engine. Use these only in strict accordance with the manufacturer's directions.

- **If the engine exhaust is not below water level, operate the engine only with adequate ventilation or exhaust removal.**

- **Do not operate the engine without the propeller and shafts being adequately secured.**

  Note: You may be tempted to check the operation of a lower unit without the housing covers being in place or without the propeller being in place or with the system in other configurations in which it is not fully assembled. However, if you do so, the components may not be adequately secure and they may then bind and break or fly apart.

- **Do not place your hands or other objects into the water near an operating propeller.**

- **Disconnect the spark-plug leads prior to servicing the propeller.**

12. Probable causes of poor boat performance related to power-output systems

- **Propeller out of balance**

  Note: Bent or broken propeller blades, bent propeller shafts, loose bearings, fouling on the propeller blades, and other factors can cause the blades to be out of balance. An out-of-balance propeller causes vibration through the whole engine, which can lead to excessive smoking and loss of power. It can further cause the boat to weave at low speeds and vibrate at high speeds.

- **Weeds or debris in propeller or lower unit**

  Note: Weeds, fishing line, and other debris can become wrapped around the propeller. This can result in several possible problems. The debris may simply increase the load on the engine, which may lead to overheating or excessive wear, or it may stop the blade completely with the probable breaking of the shear pin or other protective device. Debris may throw the propeller out of balance. Debris may also disrupt the water stream and affect the boat's maneuverability.

- **Binding of the lower unit**

  Note: Binding of the lower unit can result from weeds or debris, damage to the drive line, lack of lubrication, and other factors. The symptoms of binding are similar to those of propeller problems, depending on whether the binding is a locked-up or intermittent binding.

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- **Incorrect propeller**

  Note: The propeller may be wrong in terms of diameter, pitch, and number of blades. The wrong propeller will lead to too much torque, power that is too great or too little, and speeds that are too slow or too fast.

- **Slippage of propeller hub**

  Note: The propeller hub may slip due to worn splines, loose bearings, or other factors depending on the design. Slippage leads to lost or erratic power.

- **Gearcase loose or worn linkage**

  Note: Worn gears, bearings, clutches, and linkages; bent and misaligned shafts; loose fasteners; and other problems can lead to a loss of power through the power-output system. Another problem is that the system may slip out of gear, such as shifting into neutral from forward or reverse.

- **Incorrect trim-tab setting**

  Note: If the trim-tab setting is incorrect, the boat will veer to one side or the other. If the trim-tab setting is not adequate to offset the effects of engine torque, the bow of the boat will tend to drift in the opposite direction of propeller rotation. If the trim-tab setting is excessive, the bow of the boat will tend to drift in the direction of propeller rotation.

13. Methods used to compensate for walking

Note: The condition known as *walking* is a tendency in the stern of the boat to move toward the direction of propeller rotation; walking is a nuisance in boat operation. The simplest way to compensate for walking is to have the operator adjust the boat steering to offset walking, just as a boat operator compensates for wind or water currents by crabbing—that is, driving the boat at a slight angle. However, crabbing has limited effectiveness for walking, which is applied primarily to the stern of the boat. Thus, as a convenience to the operator, most manufacturers choose to build ways of compensating for walking into the boat or engine design.

- **Set the trim tab to offset the amount of walking.**

  Note: As you learned in Objective 1, the trim tab is a small rudder that can be adjusted or that is set to redirect a portion of the thrust of the propeller in the direction of blade rotation to offset walking. In many designs, the trim tab also contains the exhaust port so that this force is added to the trim effect. This offers the further advantage that the flow of exhaust gases increases with increased engine speed.

- **Offset the engine from the center of the transom.**

- **Use an engine that has the lower unit offset from center.**

- **Use two engines with propellers that rotate in opposite directions.**

- **Properly maintain the engine.**

  Note: Walking is sometimes the result of poor engine performance or damage. For example, if the skeg is damaged or missing, the boat is likely to walk, especially at low speeds.

Operation and Service of Power-Output Systems
Unit 3

Student Supplement 1—Principles of Propeller Operation

Introduction

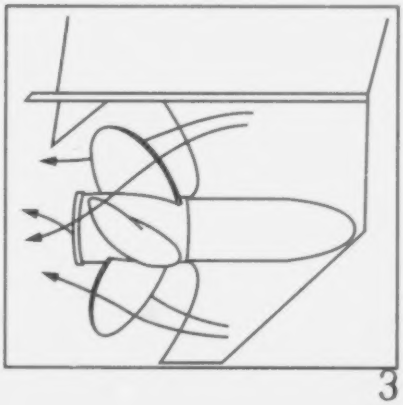
In your studies of power product equipment, you may have studied rotary pumps. Internal-combustion engines are often used to power pumps that move fluids—air and water—from one place to another. For example, power product equipment engines may be used to provide the driving force for pumps in irrigation systems or pressurized spray systems. Essentially, an outboard engine serves the same purpose. The driving force that moves a boat forward is the result of the outboard propeller moving water from one side of the propeller blades to the other. In order to control the operation of the boat most efficiently, outboard engines and propellers must be precisely designed because many forces are at work in the movement of water from one side of the propeller to the other.

The service technician should not forget that an outboard engine is a specialized water pump powered by an internal-combustion engine. For this reason, technicians must understand how a water pump works and the dynamics of that operation. Further, technicians must be familiar with the specific applications of an outboard engine as a water pump. The most-important link in the process of determining the specifications of pump effectiveness is the propeller. This supplement covers the science of water pumps and propellers so that you will better understand how outboard engines operate.

Movement of water

The function of the propeller is to move water past its blades. This is accomplished by displacing water on one side of the blades with water moving in to replace the displaced water. As shown in Figure 1, the movement of the blade causes water to slide along the blade. The blade acts as a wedge, splitting the water. The portion of the blade that starts the wedge action is called the *leading edge,* while the edge on the back side of the blade is known as the *trailing edge.* As the wedge cuts through the water, the water on the back side of the blade must move faster than the water on the front side of the blade. This creates an area of lower pressure on the trailing side of the blade. Water ahead of the blade flows to the area of lower pressure.

Figure 1: Movement of water past a propeller



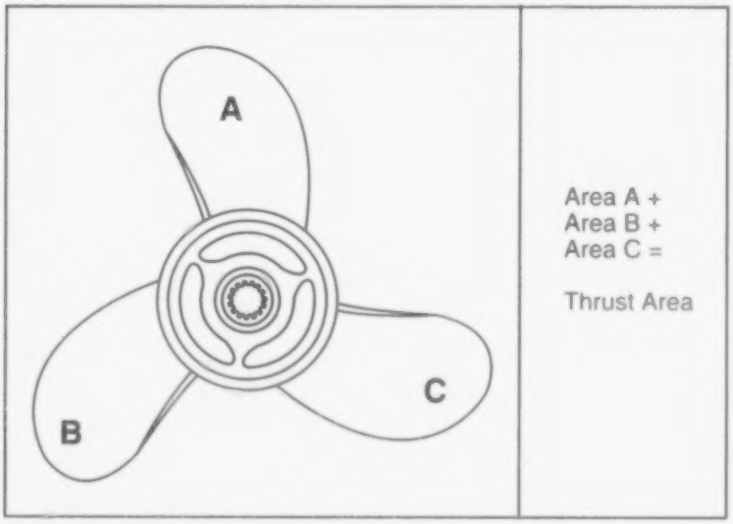
Student Supplement 1

In a conventional water pump, water is pushed past the pump and the pump remains stationary. In the case of an outboard engine, the pump is not rigidly fixed. According to a law of physics, when force is applied, there will be an equal reaction in the opposite direction. Thus, when water is moved past the blades of the propeller, the propeller is thrust in the opposite direction, pushed by the water it has displaced.

Thrust area

One of the determining factors in the amount of thrust created is the amount of water moved during each revolution of the propeller. Several characteristics of the propeller govern the amount of water that is displaced with each revolution. One of the most critical is called *thrust area.* Thrust area is the profile area of the blade that is available to move water, as shown in Figure 2. If the blade is compared to a paddle, it becomes obvious that a larger-area paddle moves more water. The main factors that determine thrust area are the diameter of the propeller and the pitch of the propeller.

Figure 2: Thrust area



Diameter

The diameter of the propeller is simply the distance across the propeller between two outside points opposite each other on a line that runs through the center of the propeller (see Figure 3-a on the next page). If you consider thrust area, you can see that thrust area tends to increase as diameter increases.

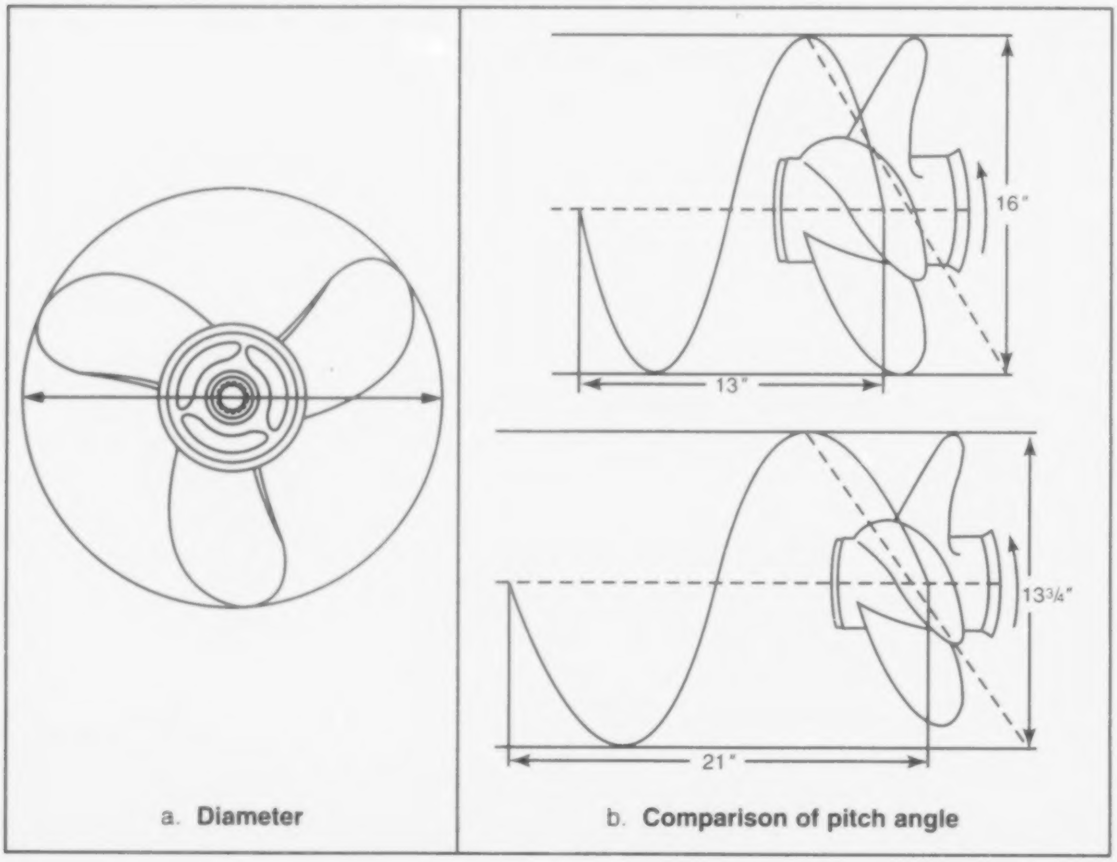
While increasing the diameter increases the thrust area, there are limits to this technique. For example, a larger-diameter propeller must ride lower in the water to avoid ventilation. Naturally, this means that there is greater danger of damage to the propeller and the boat is restricted from operating in shallow water. Larger blades are heavier and offer more resistance to turning in the water, which places greater load on the engine. Obviously then, there is a critical balance between propeller diameter and engine efficiency so that after a certain point there is no gain in thrust with a larger-diameter propeller with the same engine output. Another consideration is that the longer a blade is, the faster the outside edge moves for a given engine speed. High blade speeds mean increased wear, greater danger of disintegration, and other possible problems. Finally, another practical limit of propeller diameter is that the longer a propeller, the more likely that it can be seriously damaged in a collision because longer blades are generally weaker.

Standard blade diameters for outboard engines typically range from approximately 5½ to 10½ inches (150 mm to 275 mm).

Pitch Pitch, as applied to outboard-engine propellers, has two distinct but closely related meanings. Pitch is basically the angle of the blade as compared to the centerline of the propeller shaft. The more-common outboard-engine characteristic described by the term *pitch* is actually forward thrust, or the distance that the boat moves during one revolution of the propeller.

Pitch, as the angle of the blades, affects thrust area because the closer that the blade is to perpendicular to the propeller shaft, the less thrust area there is to apply to the displacement of water. This is shown in the comparison of two propellers of different pitches in Figure 3-b below.

Figure 3: Diameter and pitch



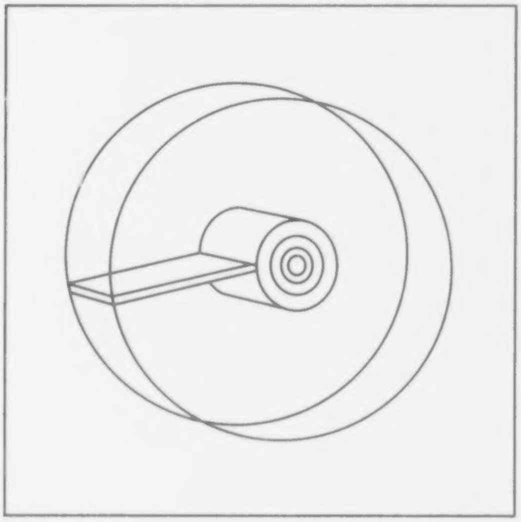
a. **Diameter**

b. **Comparison of pitch angle**

Student Supplement 1

To understand the role of pitch (blade angle) in generating thrust (forward movement), think of a propeller with one blade. As the propeller rotates, it pushes water out of its path. The amount of water moved during one rotation is equal to the volume of a cylinder of water defined by the diameter and pitch of the blade. If there are two blades, then approximately twice as much water is displaced. In a simplified way, Figure 4 below shows how the angle of the blade affects the forward movement of the boat. Assume that the blade is 3 inches (75 mm) wide so that the cylinder of water being moved is that length. If the propeller has two blades, then the cylinder length is doubled to 6 inches (150 mm). This approximates the theoretical pitch of the propeller.

Figure 4: Theoretical pitch



There are two types of pitch: fixed and variable. A propeller with a fixed pitch has blades set at a single angle across their width. A propeller with variable pitch, generally called a *cup propeller*, has a curved edge so that the pitch at the leading edge of the propeller is closer to perpendicular to the propeller shaft while the pitch of the trailing edge is closer to parallel to the propeller shaft. This design forms a pocket similar to that of a baseball mitt so that it scoops water and pushes it along. This shape also accelerates the water as the leading edge moves through it and then the curve down to the trailing edge directs thrust rearward. The accelerated motion to the rear also helps to pull water into the area of displaced water on the forward side of the blade.

Propeller pitch can be thought of as comparable to transmission-gear ratios in land vehicles. Depending on the use of the watercraft, pitch can be used to create a high-power low gear or a fast high gear. Power output is increased by using a steep blade angle and more blades. In this way, each blade moves less water and the speed is less, but the forward thrust is more powerful. By increasing the pitch and using two blades, the speed of the boat can be increased.

Student Supplement 1

Some propellers are constructed so that the pitch of the propeller can be varied. This is to improve propeller efficiency as the speed of the boat varies. A single pitch provides maximum efficiency for a specific rate of rotation. Thus, engine efficiency can be improved by varying the pitch to match the rate of rotation.

Having a variable pitch increases the complexity and expense of a power-output system. For that reason, most engines have fixed- rather than variable-pitch blades. However, many propeller blades use a curved design called *cupping*. The curve in the blade means that the blade does not have a single pitch angle. In this way, a portion of the blade contributes to maximum efficiency as the rate of rotation varies.

Other factors

Slippage. Other factors affect the efficiency of the power-output system as it relates to propellers. For example, as was explained previously, pitch is the theoretical distance that a boat will travel as a result of one revolution of the engine. However, factors such as the difference between actual pitch and the pitch of maximum engine efficiency mean that full theoretical thrust is never achieved. This difference between the distance defined by the theoretical thrust and the actual distance traveled by the boat is called *slippage*. Other sources of slippage related to the propeller include the fact that not all of the thrust is directed horizontally and the disruption of water flow caused by the turbulence of the turning blades. For a slow-moving boat, slippage may equal more than half the theoretical pitch, while a race boat may have slippage of 10 percent or less.

Speed of operation. The intended speed of operation of the boat is also a factor in determining how many blades the propellers should have. For example, if two propellers have the same diameter and pitch but one has two blades and the other has three blades, the one with three blades will produce more thrust at a specific engine speed. The one with two blades will have a lower thrust but will be capable of producing more forward speed, especially in a boat that rides high in the water.

Walking. Another effect of propeller operation that reduces the amount of thrust applied to moving the boat forward is a result of the rotary movement of the propeller. Not all of the water passed through the blades is moved horizontally. The blades are also moving water toward their axis of rotation. This causes an outward thrust, which creates a tendency in the stern of the boat to move toward the direction of propeller rotation. This tendency is referred to as *walking*. There are three common ways of offsetting the effects of walking. One common practice is to set the trim tab at an angle to divert a portion of the thrust in the opposite direction of walking. A second method is to offset the engine mounting slightly from the centerline of the boat. In this way, the nose of the boat is pushed slightly away from the side on which the engine is offset. Finally, on boats with two engines, the direction of propeller rotation is opposite each other in the two engines, creating equal walking to each side. The use of a propeller that turns in the opposite direction of normal rotation is called *counter-rotation*.

Cavitation. Power-output efficiency is also reduced if there are bubbles in the water stream of the propeller. This is a basic condition of pumps called *cavitation*. Some entrapment of air bubbles in the water stream is unavoidable, but if the corrosion eats into the streamlining of the lower unit or debris gets caught on the lower unit or exhaust is directed into the water stream, excessive air bubbles can result. Air bubbles reduce efficiency because air, unlike water, compresses under pressure. Thus, a rotating blade pushing against water will produce an equal amount of propulsion force in the other direction. But a blade pushing against bubbles will compress the air inside the bubbles, resulting in a loss of force.

Ventilation. A common cause of cavitation is called *ventilation*. Ventilation is often referred to as *cavitation*. However, ventilation is simply one operating factor that can lead to introducing bubbles into the water stream. Ventilation results when the blades of the propeller break the surface of the water. This causes the blades to sweep air ahead of them into the water, thus causing cavitation. Ventilation occurs when the mounting height of the engine is incorrect, the engine is tilted too high, or the boat is riding too high in the water.

These concepts should help you understand the importance of having a properly mounted engine with the correct propeller in order for the boat to operate as required for its intended use.

Operation and Service of Power-Output Systems
Unit 3

Student Supplement 2—Hardware Used in Power-Output Systems

Introduction

Hardware is used on all types of engines and equipment. You have studied many types of hardware and fasteners in your previous studies of other types of power product equipment. Many of those types of hardware and fasteners are also used in outboard engines. However, outboard engines also use many types of hardware and fasteners not commonly found in other applications. This is particularly true of the power-output system. This supplement discusses some of the unique pieces of hardware and fasteners that you are likely to encounter when servicing the power-output system.

Types of hardware

Traditional fasteners, such as screws and bolts, are used throughout the outboard engine. However, the power-output system has some unique fastener and hardware applications. For example, the use of pins and splined devices is more common in the power-output system than in most other systems. For more information about most of the hardware listed below, see MAVCC's *Power Product Equipment Technician: Theory and Principles of Engine Operation,* Unit 3, "Common Fasteners."

- **Keys**—Hold components in position on shafts (see Figure 1-a on page 173)

  Keys come in a number of designs. Two of the most popular are the Woodruff or half-moon and the plain or straight key. They work by fitting into a slot on a shaft while a second part fits over the shaft and the key. In this way, the key holds the second part in position on the shaft.

- **Snap rings**—Provide a barrier to prevent movement of other components past a certain point (see Figure 1-b on page 173)

  Snap rings normally fit into a groove machined into a circular part. Snap rings may be internal or external. Internal snap rings fit into a groove on the inner surface of a component, such as the inside of a bearing housing. External snap rings fit into grooves on the exterior surface of a circular part, such as a shaft. In both designs, only a portion of the snap ring rests in the groove. The exposed portion of the ring serves to hold a part in place or to prevent a moving part from going past a certain point.

- **Shear pins**—Hold the propeller to the propeller shaft, or hold sections of the drive shafts together (see Figure 1-c on page 173)

  Shear pins are designed to hold parts together until subjected to a force that might damage the components. At that point, the shear pin breaks so that other components are not damaged.

- **Dowel pins**—Hold two parts in a desired position to each other (see Figure 1-c on page 173)

  Sometimes called *locating pins,* dowel pins protrude from one part and fit into a hole in a mating part.

Student Supplement 2

- **Cotter pins**—Inserted through a hole and deformed to hold two parts together (see Figure 1-c on page 173)

- **Couplings**—Join two other components, usually by fitting over a threaded portion of the other components (see Figure 1-d on page 173)

  Couplings are normally threaded so that another threaded part can fit on each end of the coupling. The threading may be either internal or external. A common use for couplings in outboard engines is to join shafts end to end.

- **Spacers**—Hold adjoining parts at a desired distance from each other (see Figure 1-e on page 173)

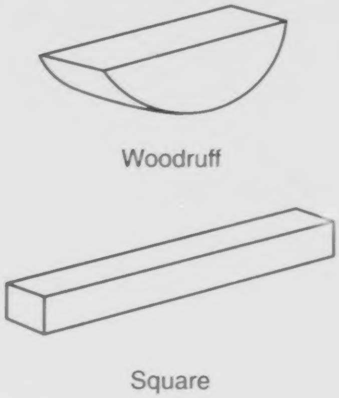
  Spacers are placed between parts to maintain a desired distance or, in some cases, orientation, such as maintaining two ends of a part level with each other. Spacers are often used in outboard engines to position parts along a shaft. Spacers are sometimes referred to as *shims.*

- **Specialty fasteners**—Serve as fasteners but also provide a second function (see Figure 1-f on page 173)

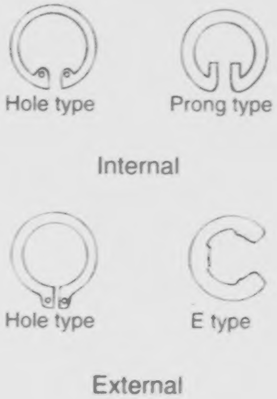
  A specialty fastener is one that functions as a typical fastener of the same type but also serves a second function. For example, propellers are often held onto the propeller shaft by a nut that threads onto the end of the shaft. In some cases, these nuts are tapered to form a streamline profile with the rest of the lower unit. Another example is the various plugs used in lower units. Most are modified screws. Some serve as drain plugs, while others serve as vent plugs and have a hole drilled through them.

Student Supplement 2

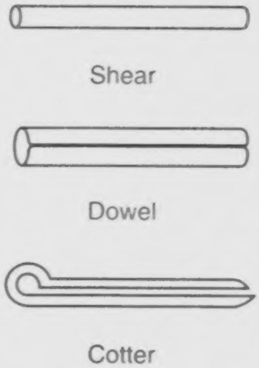
Figure 1: Hardware used on power-output systems


Woodruff
Square

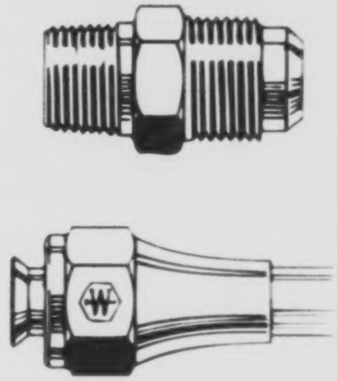
a. **Keys**


Hole type
Prong type
Internal
Hole type
E type
External

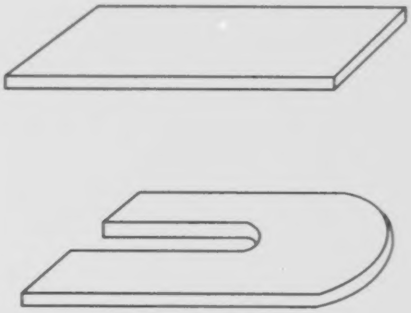
b. **Snap rings**


Shear
Dowel
Cotter

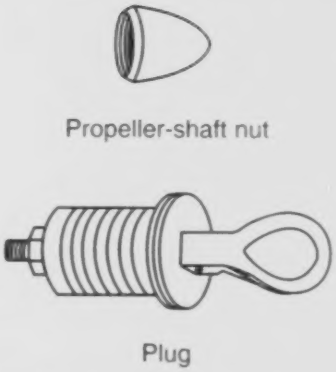
c. **Pins**



d. **Couplings**



e. **Spacers (shims)**


Propeller-shaft nut
Plug

f. **Specialty fasteners**

Operation and Service of Power-Output Systems
Unit 3

Assignment Sheet 1—Determine Parts and Specifications for Power-Output Systems

Name ______________________________ Date ________________

Evaluation criteria **Rating**

Directions have been followed. _______

Minimum of 85 percent of answers are correct. _______

Overall rating _______

Evaluator's comments ______________________________

____

____

Introduction

The power-output system of an outboard engine is roughly equivalent to the drive-train section of land-based power product equipment. Many authorities equate the gearcase to the transmission or transaxle. The gearcase defines the gear ratio and normally houses the linkage necessary to shift between forward and reverse. The propeller shaft is comparable to the drive axle in a land-based system. The propeller shaft drives the propeller, which creates a propulsion stream similar to the traction provided by a drive wheel. Thus, the power-output system is vital to the operation of the boat. Even when the engine is functioning at peak performance, the boat will not operate properly if the power-output system is not working well. This assignment sheet will give you practice in selecting parts and determining specifications for power-output systems that you are likely to service in your career as an outboard-engine technician.

Exercise

Directions

Using the resources available in your facility, determine the part numbers and specifications requested. Write your answers on the blanks provided with each question.

Assignment Sheet 1

1. The illustration in Figure 2 on the next page shows the gear housing for a Mercury/Mariner 9.9-horsepower engine with a serial number above OG590000. List the numbers in the illustration used to identify the following parts.

	Part	Part number
a.	Pinion gear	
b.	Drive shaft	
c.	Shift shaft (upper)	
d.	Shift shaft (lower)	
e.	Gearcase drain screw	

2. For the engine shown in Figure 2, adjustment of the shift rod is required during reassembly (this is shown in Figure 1 below). The shift-rod height is adjusted by screwing the shift rod in or out of the shift cam (see Figure 1). Answer the following questions about that adjustment.

   a. Is the shift-rod adjustment made with the gearcase in neutral, forward, or reverse? Circle the correct answer below.

      Neutral Forward Reverse

   b. What is the adjustment procedure? Describe the adjustment procedure on the blank lines below.

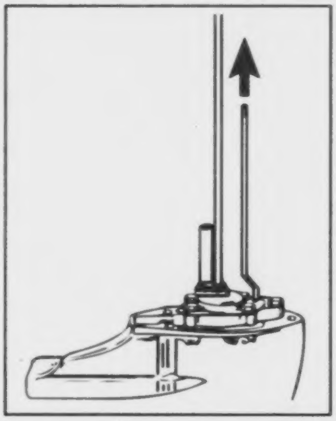
      Adjustment — ______________________________

      ____

      ____

      ____

Figure 1: Shift-rod adjustment



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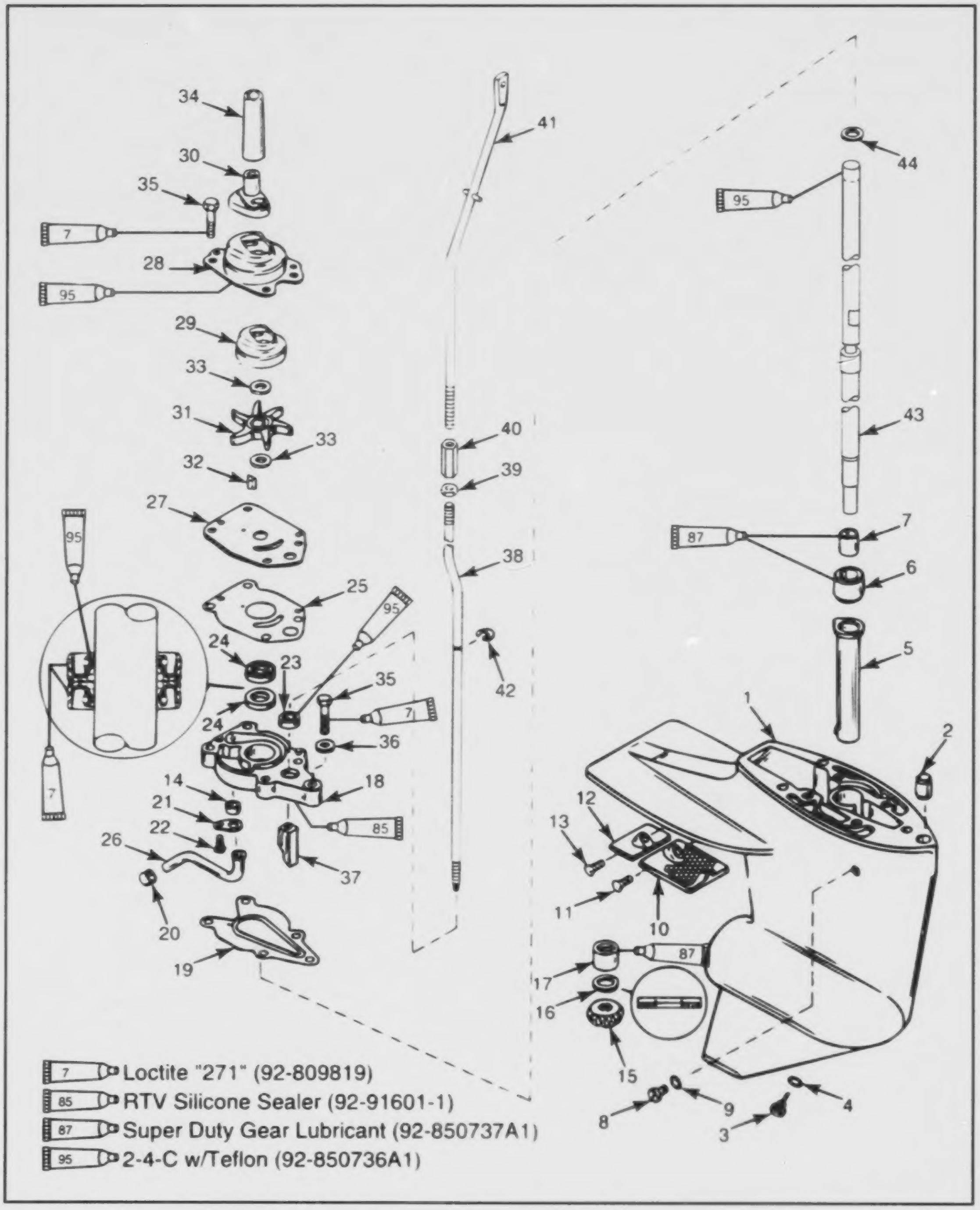
Assignment Sheet 1

Figure 2: Gear housing for a Mercury Mariner 9.9-horsepower engine with a serial number above OG590000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7
6
5
1
2
12
13
11
10
17
87
16
15
8
9
3
4
7 Loctite "271" (92-809819)
85 RTV Silicone Sealer (92-91601-1)
87 Super Duty Gear Lubricant (92-850737A1)
95 2-4-C w/Teflon (92-850736A1)

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Assignment Sheet 1

3. Figure 3 on the next page shows a portion of a Tanaka TOB-300 power-output system.

   a. What part number in the illustration indicates the propeller shaft?

      Part number — ____________________

   b. What part number in the illustration is used to label the drive shaft?

      Part number — ____________________

   c. What part number in the illustration is the propeller shear pin?

      Part number — ____________________

   d. What part number in the illustration is used to identify the pinion gear?

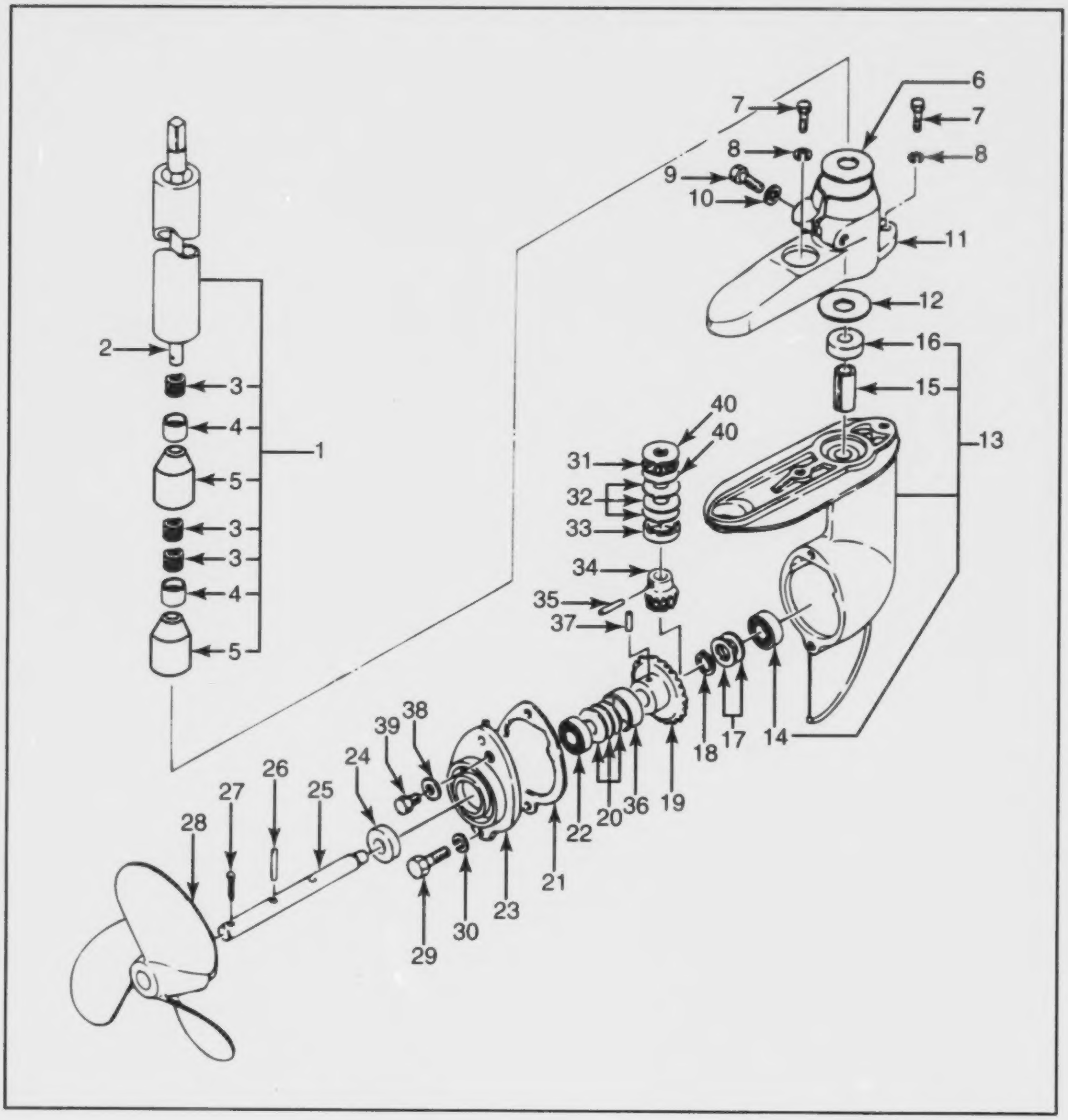
      Part number — ____________________

   e. What is the function of the part identified as 16 in the illustration?

      Function — ____________________

Assignment Sheet 1

Figure 3: Tanaka TOB-300 power-output system (exploded view of lower-unit assembly)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Assignment Sheet 1

4. Figure 4 on the next page shows some of the power-output-system components of Johnson models such as 2, 2.3, 3.3, 4, 5, 6, and 8.

   a. What number in the illustration is used to label the drive shaft?

      Part number — ______________________

   b. What is the recommended lubricant for refilling the gearcase?

      Lubricant — ______________________

   c. What is the maximum allowable end play for the propeller shaft?

      End play — ______________________

   d. What part is identified as 3 in the illustration?

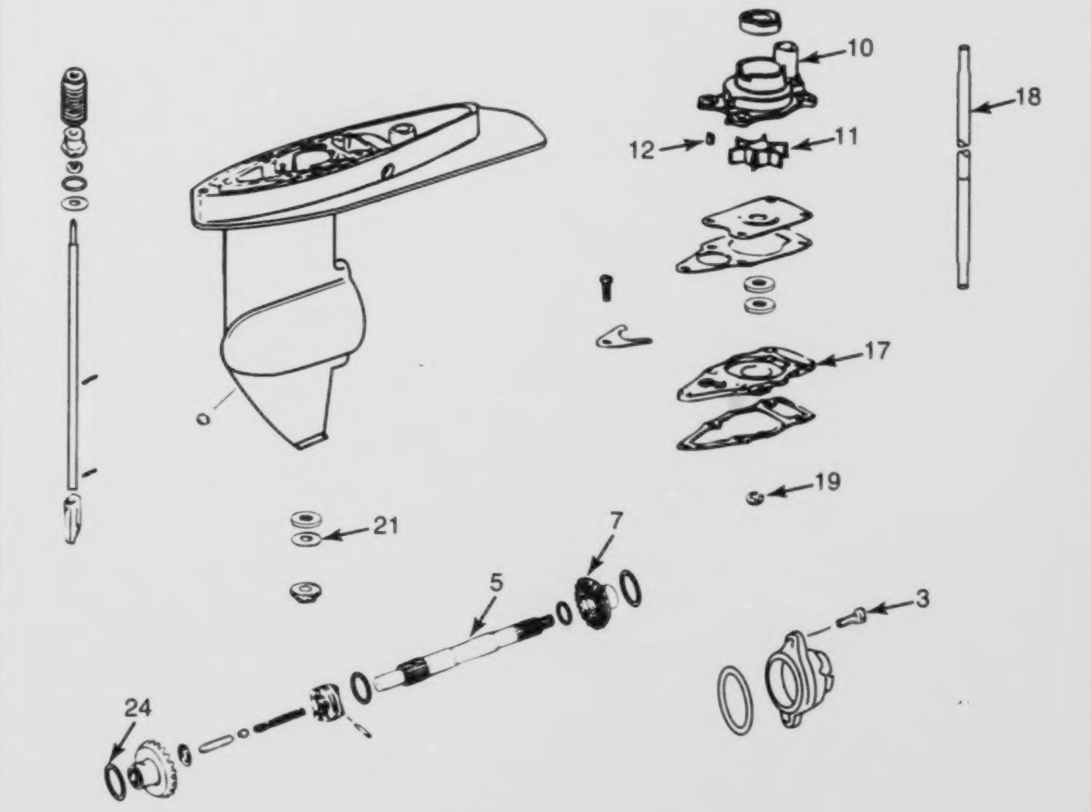
      Part name — ______________________

   e. What is the recommended torque value for the part labeled as 3?

      Torque value — ______________________

Assignment Sheet 1

Figure 4: Johnson power-output-system components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12
11
17
19
21
7
5
3
24

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Assignment Sheet 1

5. Some of the components of the power-output system of Evinrude 200- and 225-horsepower FFI models are shown in Figure 5 on the next page.

   a. The numbers in circles indicate lubricant and sealant requirements. What type of lubricant or sealant is required for each of the following applications?

      1) Shift-shaft threads — ______________________________

      ____

      2) Forward O-ring flange of the propeller-shaft bearing housing — ______________________________

      3) Aft support flange of the propeller-shaft bearing housing — ______________________________

      4) Retaining screws for the propeller-shaft bearing housing — ______________________________

      5) Drive-shaft splines — ______________________________

   b. Before refilling the gearcase on this engine, the manufacturer recommends that a pressure gauge be used to test for leaks. What is the recommended increase in pressure for this test?

      Pressure increase — ______________________________

   c. A particular engine uses a 25-inch (635 mm) shift rod. What is the recommended adjusted height as measured from the shift-rod hole to the surface of the gearcase?

      Height — ______________________________

   d. When adjusting the shift-rod height, what position should the shift mechanism be in? (Circle the correct answer)

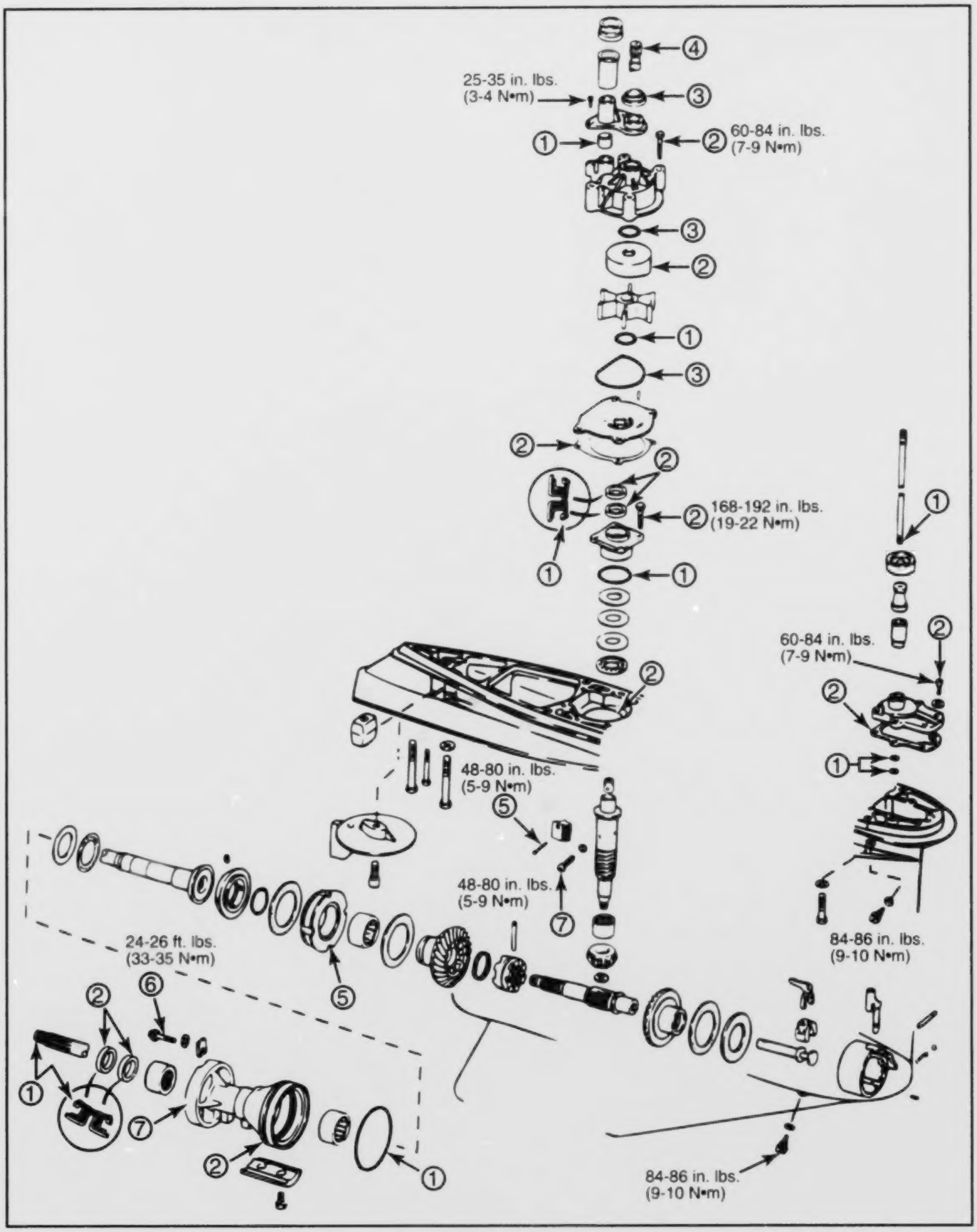
      Forward Neutral Reverse

   e. What is the recommended torque value for the trim-tab retaining screw?

      Torque value — ______________________________

Assignment Sheet 1

Figure 5: Evinrude power-output system, 200- and 255-horsepower FFI models


④
25-35 in. lbs.
(3-4 N•m)
③
①
② 60-84 in. lbs.
(7-9 N•m)
③
②
①
③
②
②
① ② 168-192 in. lbs.
(19-22 N•m)
①
①
①
60-84 in. lbs.
(7-9 N•m)
②
②
②
①
48-80 in. lbs.
(5-9 N•m)
⑤
48-80 in. lbs.
(5-9 N•m)
⑦
84-86 in. lbs.
(9-10 N•m)
24-26 ft. lbs.
(33-35 N•m)
⑤
⑥
②
①
⑦
②
①
84-86 in. lbs.
(9-10 N•m)

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Operation and Service of Power-Output Systems
Unit 3

Assignment Sheet 2—Interpret a Power-Output-System Troubleshooting Chart

Name ______________________________ Date ____________________

Evaluation criteria	Rating
Directions have been followed.	______
Minimum of 85 percent of answers are correct.	______
Overall rating	______

Evaluator's comments ____

____

____

Introduction

An outboard engine may be working perfectly, but boat performance will still be affected if the engine's power output is faulty. Because problems in the drive shaft and the lower unit can lead to a number of different performance symptoms, a technician must fully understand how to determine the probable causes of power-output-system problems. Generally, this means that the technician must know how to interpret troubleshooting charts. In this assignment sheet, you will practice applying troubleshooting procedures dealing with the power-output system.

Exercise

Directions

Using the resources available in your facility and the troubleshooting chart included in this assignment sheet, answer the following questions. Write an "X" on the blank before the correct answer with each of the items below and on the next page.

1. An engine overheats. Which of the following is **not** a likely cause of the problem?

   ______ a. Plugged water inlet

   ______ b. Defective impeller

   ______ c. Flywheel key sheared

   ______ d. Engine not deep enough in the water

Assignment Sheet 2

2. Which of the following is a problem that is likely to be caused by having the wrong propeller?

_______ a. No power under heavy load

_______ b. Engine dies when given full throttle

_______ c. Engine will not crank

_______ d. Engine knocks excessively

3. An outboard engine stops suddenly and seems to be frozen up. Technician A suggests that the problem could be that the crankshaft may be rusted. Technician B suggests that the propeller shaft may be bent or broken. Who is correct?

_______ a. Technician A

_______ b. Technician B

_______ c. Both Technician A and Technician B

_______ d. Neither Technician A nor Technician B

4. The top rpm is 30 percent less than what it should be. Which of the following is a likely problem?

_______ a. Too much oil in the fuel

_______ b. Too much oil in the lower unit

_______ c. Incorrect propeller

_______ d. Bent propeller shaft

5. An engine runs well for a short period of time and then slows and stops. Technician A says that the problem must be in the fuel or ignition system. Technician B says that the problem can be caused by an incorrect propeller. Who is correct?

_______ a. Technician A

_______ b. Technician B

_______ c. Both Technician A and Technician B

_______ d. Neither Technician A nor Technician B

Assignment Sheet 2

Troublshooting Chart

The following chart lists 25 engine-performance problems and their probable causes.

1. **Starter rope does not return**
   - Recoil spring broken or binding
   - Starter housing bent
   - Loose or missing parts
2. **Manual starter clatters**
   - Friction spring bent or burred
   - Starter housing bent
   - Excess grease on pawls or spring
   - Dry starter sprindle
3. **Electric starter is inoperative**
   - Loose or corroded connections or ground
   - Starting-circuit safety switch open, or out of adjustment
   - Under capacity or weak battery or corroded battery terminals
   - Faulty starter solenoid
   - Moisture in electric starter motor
   - Broken or worn brushes in starter motor
   - Faulty fields
   - Faulty armature
   - Broken wire in harness or connector
   - Faulty starter key or pushbutton switch
   - Worn or frayed insulation
4. **Electric starter does not engage but solenoid clicks**
   - Loose or corroded connections or ground
   - Weak battery
   - Faulty starter solenoid
   - Broken wire in electric harness
   - Loose or stripped post on starter motor
   - See steps in number 3
5. **Engine is hard to start or won't start**
   - Empty gas tank
   - Gas-tank air vent not open
   - Fuel lines kinked or severely pinched
   - Water or dirt in fuel system
   - Clogged fuel filter or screens
   - Engine not being choked to start
   - Engine not primed—pump primer system
   - Carburetor adjustments too lean (not allowing enough fuel to start engine)
   - Timing and synchronizing out of adjustment
   - Manual choke linkage bent—auto choke out of adjustment
   - Spark plugs improperly gapped, dirty, or broken
   - Fuel-tank primer inoperative (pressurized system)
   - Ignition points improperly gapped, burned, or dirty
   - Loose, broken wire or frayed insulation in electrical system
   - Reed valves not seating or stuck shut
   - Weak coil or condenser
   - Faulty gaskets
   - Cracked distributor cap or rotor
   - Loose fuel connector
   - Electronic-ignition component malfunction

5. **Engine is hard to start or won't start** (cont.)
   - Faulty fuel pump
   - Dirty or inoperative fuel injectors
6. **Low-speed miss or engine won't idle smoothly and slowly enough**
   - Too much oil – too little oil
   - Timing and synchronizing out of adjustment
   - Carburetor idle adjustment (mixture lean or rich)
   - Ignition points improper (gap, worn or fouled)
   - Weak coil or condenser
   - Loose or broken ignition wires
   - Loose or worn magneto plate
   - Spark plugs (improper gap or dirty)
   - Head gasket, reed-plate gasket (blown or leaking)
   - Reed valve standing open or stuck shut
   - Plugged crankcase bleeder, check valves, or lines
   - Leaking crankcase halves
   - Leaking crankcase seals (top or bottom)
   - Exhaust gases returning through intake manifold
   - Electronic-ignition component malfunction
7. **High-speed miss or intermittent spark**
   - Spark plugs improperly gapped or dirty
   - Loose, leaking, or broken ignition wires
   - Breaker points (improper gap or dirty; worn cam or cam follower)
   - Weak coil or condenser
   - Water in fuel
   - Leaking head gasket or exhaust-cover gasket
   - Spark-plug heat range incorrect
   - Engine improperly timed
   - Carbon or fouled combustion chambers
   - Magneto or distributor poorly grounded
   - Distributor oiler wick bad
   - Electronic-ignition component malfunction
8. **Engine coughs, spits, slows**
   - Idle or high-speed needles set too lean
   - Carburetor not synchronized
   - Leaking gaskets in induction system
   - Obstructed fuel passages
   - Float level set too low
   - Improperly seated or broken reeds
   - Fuel-pump pressure line ruptured
   - Fuel pump (punctured diaphragm), check valves stuck open or closed, fuel lines leak
   - Poor fuel-tank pressure (pressurized system)
   - Worn or leaking fuel connector
9. **Engine vibrates excessively or runs rough and smokes**
   - Idle or high-speed needles set too rich
   - Too much oil mixed with gas
   - Carburetor not synchronized with ignition properly
   - Choke not opening properly
   - Float level too high
   - Air passage to carburetor obstructed

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Assignment Sheet 2

Troublshooting Chart

(continued)

9. Engine vibrates excessively or runs rough and smokes (cont.)
- Bleeder valves or passages plugged
- Transom bracket clamps loose on transom
- Propeller out of balance
- Broken engine mount
- Exhaust gases getting inside motor cover
- Poor ignition – see number 7

10. Engine runs well, idles well for a short period, then slows down and stops
- Weeds or other debris on lower unit or propeller
- Insufficient cooling water
- Carburetor, fuel pump, filter, or screens dirty
- Bleeder valves or passages plugged
- Lower-unit bind (lack of lubrication or bent)
- Gas-tank air vent not open
- Not enough oil in gas
- Combustion chambers and spark plugs fouled, causing preignition
- Spark-plug heat range too high or too low
- Wrong propeller (preignition)
- Slow-speed adjustment too rich or too lean

11. Engine won't start, kicks back, backfires into lower unit
- Spark-plug wires reversed
- Flywheel key sheared
- Distributor-belt timing off (magneto or battery ignition)
- Timing and synchronizing out of adjustment
- Reed valves not seating or broken

12. Engine will not accelerate, low top rpm
- Improper carburetor adjustments
- Improper timing and synchronization
- Spark plugs (improper gap or dirty)
- Ignition-system malfunction
- Faulty coil or condenser
- Loose, leaking, or broken ignition wires
- Reed valves not properly seated or broken
- Blown head or exhaust-cover gasket
- Weeds on lower unit or propeller
- Incorrect propeller
- Insufficient oil in gas
- Insufficient oil in lower unit
- Fuel restrictions
- Scored cylinder – stuck rings
- Marine growth, hooks, rockers, or change in load of boat
- Sticky magneto plate
- Carbon buildup on piston head at deflector

13. Engine will not accelerate, idles well but when put to full power dies down
- High- or low-speed needle set too lean
- Dirt or packing behind needles and seats
- High-speed nozzle obstructed
- Float level too low
- Choke partly closed
- Improper timing and synchronization

13. Engine will not accelerate, idles well but when put to full power dies down (cont.)
- Fuel lines or passages obstructed
- Fuel filter obstructed
- Not enough oil in gas
- Breaker points improperly gapped or dirty
- Bent gearcase or exhaust tube

14. Engine runs at high speed only by using hand primer
- Carburetor adjustments
- Dirt or packing behind needles and seat
- Fuel lines or passages obstructed
- Fuel line leaks
- Fuel pump not supplying enough fuel
- Float level too low
- Fuel filter obstructed
- Fuel tank or connector at fault

15. Engine has no power under heavy load
- Wrong propeller
- Weeds or other debris on lower unit or propeller
- Breaker points improperly gapped or dirty
- Stator plate loose
- Ignition timing over advanced or late
- Faulty carburetion and/or faulty ignition
- Propeller hub slips
- Scored cylinders or rings stuck
- Carbon buildup on piston head at deflector

16. Engine cranks over extremely easily on one or more cylinders
- Low compression
  - Worn or broken rings
  - Scored cylinder or pistons
  - Blown head gasket
  - Loose spark plugs
  - Loose head bolts
  - Crankcase halves improperly sealed
  - Burned piston

17. Engine won't crank over
- Manual-start lock improperly adjusted
- Pistons rusted to cylinder wall
- Lower-unit gears, prop shaft rusted or broken
- Broken connecting rod, crankshaft, or driveshaft
- Coil heels binding on flywheel
- Engine improperly assembled

18. Engine overheats
- Engine not deep enough in water
- Not enough oil in gas or improperly mixed
- Bad thermostat
- Seals or gaskets (burned, cracked, or broken)
- Impeller key not in place or broken
- Plugged water inlet, outlet, or cavity
- Obstruction in water passages
- Broken, pinched, or leaking water lines
- Improper ignition timing
- Engine not assembled properly

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Assignment Sheet 2

Troublshooting Chart

(continued)

18. Engine overheats (cont.)
- Shortened heat-light wiring
- Bad water-pump impeller, plate, housing, or seal

19. Engine stops suddenly, freezes up
- No oil in gas, or no gas
- Insufficient cooling water
- No lubricant in gearcase
- Rusted cylinder or crankshaft
- Bent or broken rod, crankshaft, drive-shaft, propeller shaft, stuck piston
- Bad water pump or plugged water passages

20. Engine knocks excessively
- Too much or not enough oil in gas
- Worn or loose bearings, pistons, rods, or wrists pins
- Over advanced ignition timing
- Carbon in combustion chambers and exhaust ports
- Manual starter not centered
- Flywheel nut loose
- Flywheel hitting coil heels
- Bent shift rod (vibrating against exhaust tube)
- Loose assemblies, bolts, or screws

21. Alternator will not charge
- Battery condition
- Connections loose or dirty
- Drive belt loose or broken
- Faulty regulator or cutout relay
- Field fuse or fusbile wire in regulator blown
- Open alternator windings
- Worn or sticking brushes and/or slip rings
- Faulty rectifier diodes
- Faulty ammeter

22. Low alternator output and a low battery
- High resistance at battery terminals
- High resistance in charging circuit
- Faulty ammeter
- Low regulator setting
- Faulty rectifier diodes
- Faulty alternator

23. Excessive battery charging
- Regulator set too high
- Regulator contacts stuck
- Regulator voltage winding open
- Regulator improperly grounded
- High resistance in field coil
- Regulator improperly mounted

24. Excessive fuel consumption
- Hole in fuel-pump diaphragm
- Deteriorated carburetor gaskets
- Altered or wrong fixed jets
- Jets improperly adjusted
- Carburetor casting porous
- Float level too high
- Loose distributor pulley

25. Shifter dog jumps
- Worn shifter dog or worn gear dogs
- Worn linkage
- Remote-control adjustment
- Gearcase loose or sprung
- Exhaust housing bent
- Linkage out of adjustment

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Operation and Service of Power-Output Systems
Unit 3

Assignment Sheet 3—Calculate Gear Ratios

Name ______________________ Date ______________

Evaluation criteria **Rating**

Directions have been followed. ______

Minimum of 85 percent of answers are correct. ______

Overall rating ______

Evaluator's comments ______________________________

____

____

Introduction There are a number of ways of determining gear ratio and of expressing the relationship. One method is to compare the number of teeth in one gear to the number of teeth in the other gear. For example, if one gear has 48 teeth and the other has 24 teeth, then the ratio between the gears is 2 to 1. Every time the larger gear rotates once, the smaller gear will make two revolutions. If the larger gear in this example is the drive gear and it rotates at 1000 rpm, the smaller gear will revolve at 2000 rpm. Thus, the gear ratio can also be calculated by using the rotational speeds of the gears.

In this assignment sheet, you will practice calculating gear ratios.

Assignment Sheet 3

Exercise

Directions For each situation described below, calculate the gear ratio. Show your calculations in the space provided under each question.

Write your answer on the blank provided with each question. State your answer so that the propeller speed represents 1 in the ratio. Thus, for a problem in which engine speed is used for the calculation, the ratio should be:

$$\frac{\text{Engine speed}}{\text{Propeller speed}} = \text{Gear ratio}$$

Therefore, if an engine operates at 2000 rpm and the propeller turns at 1000 rpm, the calculation would be

$$\frac{2000\text{ rpm}}{1000\text{ rpm}} = 2$$

so the gear ratio would be 2:1.

If the problem gives the number of teeth in each gear, use the number of teeth in the driven gear to represent 1 in the ratio and calculate as:

$$\frac{\text{Teeth in drive gear}}{\text{Teeth in driven gear}} = \text{Gear ratio}$$

1. An outboard engine has a propeller speed of 2000 rpm when the engine is operating at 6000 rpm. What is the gear ratio?

   Gear ratio — ______________________________

2. An engine has a driven gear with 30 teeth and a drive gear with 45 teeth. What is the gear ratio?

   Gear ratio — ______________________________

Assignment Sheet 3

3. An engine has a propeller speed of 4500 rpm when the engine is operating at 4500 rpm. What is the gear ratio?

   Gear ratio — ____________________

4. The driven gear in an engine has 20 teeth while the drive gear has 35 teeth. What is the gear ratio?

   Gear ratio — ____________________

5. A technician tests a propeller and determines that it is operating at 7000 rpm when the engine is running at 3500 rpm. What is the gear ratio?

   Gear ratio — ____________________

Operation and Service of Power-Output Systems
Unit 3

Assignment Sheet 4—Determine Correct Propeller Characteristics for Specific Applications

Name ______________________________ Date ______________

Evaluation criteria	**Rating**
Directions have been followed.	_______
Minimum of 85 percent of answers are correct.	_______
Overall rating	_______

Evaluator's comments ______________________________

____

____

Introduction

An owner generally wants to use a boat for a specific purpose, such as trolling for fish, water skiing, racing, or some other use. The differences in requirements for speed, torque, and other performance factors are achieved by properly matching the engine and the boat. While the engine horsepower and gearcase ratios are important, the propeller is also a critical element in the boat's power package. Several characteristics of a propeller affect its performance, including number of blades, diameter, and pitch. Other considerations in selecting a propeller include the material used, hub diameter, fixed versus varying pitch, etc. It is important for a power product equipment technician to understand these factors so that he or she can properly evaluate a boat's performance. For example, a customer may come in asking to have an engine tuned up or overhauled because the engine is not producing enough power to drive the boat as fast as desired. However, the real problem may be the propeller, and if the technician does not understand this, a lot of time may be wasted doing unnecessary troubleshooting of the engine. This assignment sheet will assist you in evaluating propellers for specific applications.

Exercise

Directions

In each of the following sections, Parts A and B, use the resources available in your facility to determine the part numbers and specifications.

In Question 1 of each section, provide the specifications requested. In Question 2 of each section, your instructor will fill out the engine information, and then you will provide the specifications requested.

Assignment Sheet 4

Part A

1. List the standard propeller characteristics requested for each engine given in the chart below. Indicate whether diameter and pitch are given in inches or millimeters.

	Manufacturer	Year	Model or hp	Diameter	Pitch	Rotation	Number of blades
a.	Chrysler	1977	20 hp				
b.	Mariner	1997	150 hp				
c.	Mercury	1998	300 hp				
d.	Evinrude	1999	90 hp				
e.	Suzuki	1983	DT 25				

2. Your instructor will complete the "manufacturer," "year," and "model or hp" columns in the chart below. Then, list the standard propeller characteristics requested for each engine given in the chart below.

	Manufacturer	Year	Model or hp	Diameter	Pitch	Rotation	Number of blades
a.							
b.							
c.							
d.							
e.							

Assignment Sheet 4

Part B 1. Another method of determining the correct propeller to use is to match the propeller to the desired engine speed at full throttle. Complete the following chart to show the recommended rpm ratings for the standard propeller.

	Manufacturer	Year	Model or hp	Low rpm	High rpm
a.	Mariner	1988	25 hp		
b.	Mercury	1990	25 hp		
c.	Evinrude	1999	225 hp FFI		
d.	Johnson	1983	7.5 hp		
e.	Yamaha	1994	4 hp		

2. Your instructor will complete the "manufacturer," "year," and "model or hp" columns in the chart below. Then, complete the chart to show the recommended rpm ratings for the standard propeller.

	Manufacturer	Year	Model or hp	Low rpm	High rpm
a.					
b.					
c.					
d.					
e.					

Operation and Service of Power-Output Systems
Unit 3

Job Sheet 1—Perform Routine Maintenance on Power-Output Systems

Introduction

This job sheet covers the routine maintenance associated with power-output systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Inspect components, including shafts, linkages, gearcase, propeller, etc.
- Change gearcase lubricant
- Adjust alignments and clearances

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of performing routine maintenance on power-output systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 1

Worksheet—Perform Routine Maintenance on Power-Output Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 1

Worksheet—Perform Routine Maintenance on Power-Output Systems

---

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Power-Output Systems
Unit 3

Job Sheet 2—Repair Power-Output Systems

Introduction This job sheet covers the repair procedures associated with power-output systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace components, including propeller, bearings, shafts, etc.
- Overhaul subsystems, including gearcase and propeller
- Perform adjustments to return system to original operating specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.
2. Watch your instructor's demonstration of repairing power-output systems and any supporting media provided by your instructor.
3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.
4. Ask your instructor to provide you with an outboard engine.
5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.
6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.
7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 2

Worksheet—Repair Power-Output Systems

Name ______________________ Attempt number ________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 2

Worksheet—Repair Power-Output Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ______________________________

____

____

Operation and Service of Power-Output Systems
Unit 3

Job Sheet 3—Remove and Replace Propellers

Introduction

This job sheet covers the procedure for removing and replacing propellers. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on a number of factors such as the type of propeller and hardware involved and the design of the power-output system, general guidelines for removing and replacing propellers include

- Handle the propeller with care
- Ensure that the propeller is the correct one for the engine, boat, and intended use
- Inspect all hardware and replace hardware that is worn or deformed; do not reuse cotter pins or shear pins
- Apply lubricants as recommended
- Observe recommended torque values

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.

2. Watch your instructor's demonstration of removing and replacing propellers and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 3

Worksheet—Remove and Replace Propellers

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ____

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________________

  Equipment model/type and code ____________________________

  ____

- Complete the following service-manual information.

  Service-manual title ___________________________________

  Section/page number of procedure _________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________________

Job Sheet 3

Worksheet—Remove and Replace Propellers

Part B: Performance evaluation

Evaluation criteria **Rating**

Correct procedures identified for assigned equipment. _______

Procedures completed correctly. _______

Proper tools used correctly. _______

Safety precautions observed. _______

Service meets specifications. _______

Clean-up and follow-up actions adequate. _______

Overall rating _______

Evaluator's comments ____

____

____

Operation and Service of Power-Output Systems
Unit 3

Job Sheet 4—Check RPM on Propellers

Introduction

This job sheet covers the procedure for checking the revolutions per minute (rpm) of propellers. While there may be variations in this procedure for specific engines, such as how the engine is mounted and the recommended idle speed, the general steps are essentially the same for most outboard engines. The procedure you use will depend on the equipment in your facilities and the engine being tested.

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.
2. Watch your instructor's demonstration of checking rpm on propellers and any supporting media provided by your instructor.
3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.
4. Ask your instructor to provide you with an outboard engine.
5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.
6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.
7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 4

Worksheet—Check RPM on Propellers

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 4

Worksheet—Check RPM on Propellers

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	
Procedures completed correctly.	
Proper tools used correctly.	
Safety precautions observed.	
Service meets specifications.	
Clean-up and follow-up actions adequate.	
Overall rating	

Evaluator's comments

Operation and Service of Power-Output Systems
Unit 3

Job Sheet 5—Perform Failure Analysis on Power-Output-System Components

Introduction This job sheet covers the procedure for performing failure analysis on power-output-system components. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. The process will consist of doing a detailed inspection of a failed power-output system to evaluate the likely cause of failure.

Procedure

1. Study the objectives in the information sheet and complete the assignment sheets.
2. Watch your instructor's demonstration of performing failure analysis on failed power-output-system components and any supporting media provided by your instructor.
3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one engine. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.
4. Ask your instructor to provide you with an outboard engine.
5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.
6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.
7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 5

Worksheet—Perform Failure Analysis on Power-Output-System Components

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 5

Worksheet—Perform Failure Analysis on Power-Output-System Components

---

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Control and Safety Systems
Unit 4

Objective Sheet

Unit objective

After completing this unit, the student should be able to describe the design and operation of outboard-engine control and safety systems and perform routine service procedures on such systems. The student should demonstrate these competencies by completing the assignment sheet and job sheets and by scoring a minimum of 85 percent on the written test.

Specific objectives

After completing this unit, the student should be able to

1. Define the terms *control system* and *safety system.*
2. State the functions of the types of control systems used with outboard engines.
3. Define the classifications of outboard-engine control systems.
4. Define the types of steering systems used with outboard engines.
5. Define the terms *tilt, trim,* and *trim tab.*
6. Describe the effect of the trim tab on boat performance.
7. List the purposes of the trim tab.
8. State the purposes of the types of hydraulic circuits used in outboard-engine control systems.
9. List the types of hydraulic cylinders used in outboard-engine control systems.
10. List the types of hydraulic fluids used in tilt and trim systems.
11. Complete guidelines for filling hydraulic systems.
12. Match the major components of remote-control assemblies to their correct functions.
13. State functions of the safety systems used with outboard engines.
14. Complete statements about the principles of operation of emergency-stop lanyards.
15. Determine control-system and safety-system service specifications and parts requirements. (Assignment Sheet 1)
16. Perform routine maintenance on steering systems. (Job Sheet 1)
17. Repair steering systems. (Job Sheet 2)
18. Perform routine maintenance on tilt and trim systems. (Job Sheet 3)

Objective Sheet

19. Repair tilt and trim systems. (Job Sheet 4)
20. Perform routine maintenance on remote-control systems. (Job Sheet 5)
21. Repair remote-control systems. (Job Sheet 6)
22. Service safety systems. (Job Sheet 7)

Operation and Service of Control and Safety Systems
Unit 4

Information Sheet

1. **Definitions of the terms *control system* and *safety system***

   - **Control system**—System that allows the operator to adjust different aspects of the engine's operation or position, such as engine speed, the direction of propeller rotation, the gearcase setting, tilt and trim, and other performance features

   - **Safety system**—System that prevents the operation of the engine or boat system during conditions when such operation might result in equipment damage or injury

2. **Types of control systems used with outboard engines and their functions**

   Note: Control systems allow the boat operator to adjust the position or operation of the engine in order to create an effect on the performance of the boat. The basic functions are to start or stop the engine, adjust its speed, and steer the direction of boat travel. Although the control systems on a particular engine or boat will vary from boat to boat, the following are the most-common control systems and their functions.

   - **Starting system**—Turns the engine flywheel to begin the internal-combustion process

     Note: The starting system may be a manual rope-rewind design or an electric starting motor.

   - **Stop system**—Prevents the spark from reaching the combustion chamber to end the internal-combustion process

     Note: The two common designs for stop systems are (1) cut-off switches and (2) ignition switches. A cut-off switch generally directs ignition current into the engine housing, thus grounding the circuit, and is commonly used on magneto ignition systems. Engines with ignition switches can be stopped simply by turning the key or switch button to the OFF position.

   - **Throttle system**—Adjusts the flow of fuel to the engine to increase or decrease engine speed

   - **Shift control**—Positions the gearcase gears to allow forward travel, reverse travel, or a neutral position

   - **Steering system**—Pivots the engine horizontally in order to change the direction of boat travel

   - **Trim-tab system**—Adjusts the engine horizontally or the flow of the water stream from the engine to keep the boat traveling in a straight line to compensate for other forces acting on the boat

     Note: Current, wind, engine torque, and other forces act on the boat so that the thrust from the propeller is not able to keep the boat traveling in a straight line. The trim tab, a small rudder behind the propeller, adjusts the angle of the water stream slightly to offset the direction of thrust.

Information Sheet

- **Tilt/trim system**—Adjusts the engine vertically to change the depth of the propeller in the water or to move the engine out of the way of obstacles

  Note: The operator may want to raise the propeller in order to move the boat through shallow water or past obstacles, to reduce boat speed, or to tow the boat.

3. Classifications of outboard-engine control systems and their definitions

Note: Outboard-engine controls are generally classified by their location. Controls are either (1) located on the engine or (2) located away from the engine and connected to the engine by means of cables, rods, electrical wiring, or other linkages.

- **On-engine controls**—Controls used to adjust the operation or position of the engine; the operator uses a control device that is located on the engine

  Note: On-engine starting systems include rope-rewind starters and buttons or switches for the starting motor. Cut-off switches are normally on the engine. Many engines incorporate the throttle control on the tiller. The tiller or a lever on the engine may control positioning of the drive gears. The tiller can also be used to steer the engine or tilt it by using the tiller as a lever to pivot the engine vertically or horizontally. Even hydraulic-tilt or trim-control buttons may be installed on the tiller or other part of the engine. The trim angle can be changed by adjusting the position of the engine or the trim tab.

- **Remote controls**—Controls used to adjust the operation or position of the engine; the operator uses a control device that is not located on the engine

  Note: Many boats are arranged so that the operator can sit in a seat in the forward section of the boat with controls placed within convenient reach. Remote starting systems are similar to those used in automobiles. Generally, a key in the ignition switch can be used to apply power to the electric starting motor. This also serves as the stop switch by turning the key to the OFF position. Throttle levers can be moved fore or aft to increase or decrease the engine speed and may include controls for the enrichment system. Levers are generally used to control the power-output-system configuration for forward or reverse travel. Remote steering systems are controlled by steering wheels located in front of the operator's seat with force transferred to the engine by means of cables, hydraulic lines, or other methods. Switches or levers allow remote control of tilt and trim functions. Many boats have a control console that includes several types of controls, such as having a set of levers for throttle, shift, tilt, and trim controls. These remote-control systems generally transfer force either mechanically or electrically.

4. Types of steering systems used with outboard engines and their definitions

Note: Outboard-engine steering systems are classified by two principal features: (1) the method for inputting force from the steering wheel to the steering linkage and (2) the type of linkage. Most small boats use a mechanical system of cables to control steering, while some large boats with outboard engines use hydraulics to pivot the engines. In some boats where the outboard engine is used for secondary power, such as sailboats, steering may be provided by a rudder system.

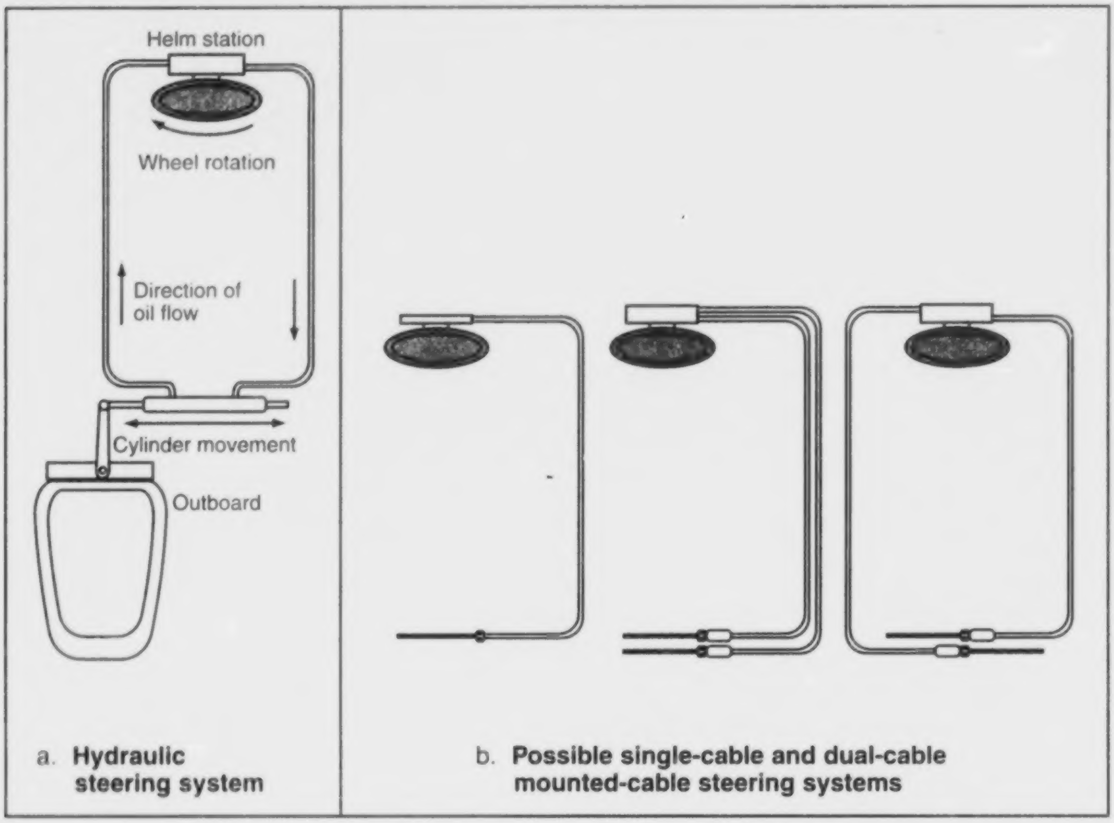
- **Hydraulic**—Steering system that uses hydraulic fluid to provide power assistance in the turning of the engine (see Figure 1-a)

  Note: Hydraulics are used to pivot the engine. Rotating the steering column causes one or the other cylinder to extend to turn the engine.

Information Sheet

- **Mounted cable**—Steering system that uses a cable that moves within a tube to transmit force mechanically from the steering column to the turning of the engine (see Figure 1-b)

Figure 1: Types of steering systems



a. **Hydraulic steering system**

b. **Possible single-cable and dual-cable mounted-cable steering systems**

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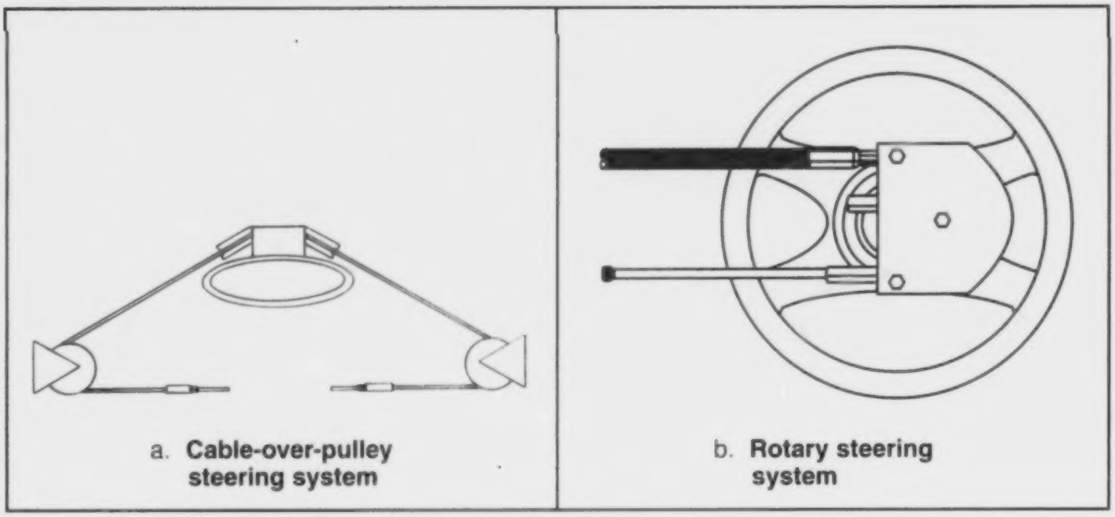
- **Cable over pulley**—Steering system that uses a cable each end of which is attached to opposite sides of the engine so that rotation of the steering wheel pivots the engine to one side or the other (see Figure 2-a on the next page)

  Note: There are two common configurations of cable-over-pulley systems. The primary difference between the two is whether the cable is routed along one side of the hull or two sides of the hull. The rigging is configured in such a way that rotation of the steering wheel pivots the engine in the direction opposite the desired path.

- **Rotary**—Steering system that uses a reel attached to the steering column so that turning the steering wheel moves the actuating mechanism (see Figure 2-b on the next page)

  Note: A rotary system actuates a cable or rod that is connected to the steering linkage. The steering linkage may be hydraulic or mechanical. Mechanical systems may be either mounted or over-pulley.

Figure 2: Types of steering systems (continued)



a. **Cable-over-pulley steering system**

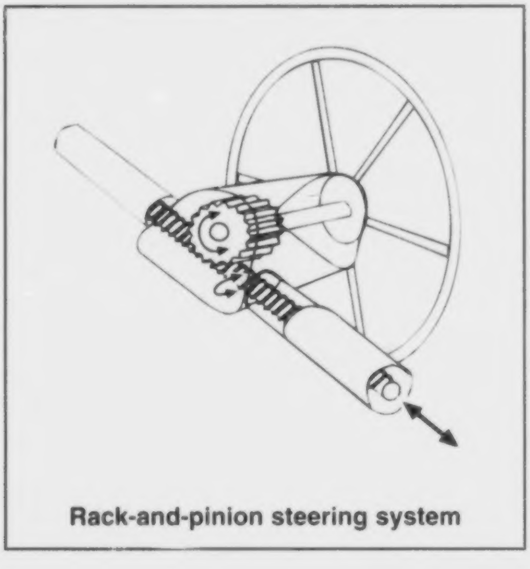
b. **Rotary steering system**

Figure 2-b reprinted with permission of Mercury Marine, Fond du Lac, Wisconsin.

- **Rack and pinion**—Steering system that uses a toothed metal bar (rack) that is free to move laterally in response to rotation of the steering column (see Figure 3)

  Note: The side-to-side movement of the rack causes the actuating mechanism to move. For example, in a mounted-cable system, one end of the cable is attached to one end of the rack so that the motion of the rack extends or retracts the other end of the cable, which is attached to the engine. This causes the engine to pivot as the rack shifts back and forth. In a cable-over-pulley system, a cable is attached to each end of the rack.

Figure 3: Types of steering systems (continued)



Rack-and-pinion steering system

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Information Sheet

5. Definitions of the terms *tilt, trim,* and *trim tab*

Note: Trim and tilt are both movements of the engine in which the lower unit pivots up and away from the transom. This allows the engine to be positioned so that the lower unit is protected from damage in shallow water and when the boat is being transported. This is referred to as *tilt*. The engine can also be tilted in order to maintain the engine perpendicular in the water. As a boat accelerates, the bow rides higher in the water. If the engine remains in a fixed position, the propeller will be forced to an angle that directs thrust downward as the bow rises. The downward thrust of the propeller output represents a loss of power and can result in a rough ride. For best power and fuel economy, the engine should be approximately perpendicular to the surface of the water. Adjustments to maintain this attitude are referred to as *trim adjustments*. In practice, trim adjustment is generally limited to less than 20 degrees of rotation. Tilt and trim can be accomplished manually or with powered systems.

- **Tilt**—Engine movement in which the engine pivots to raise or lower the gearcase in order to protect the engine from damage in shallow water or to trailer the boat
- **Trim**—Engine movement in which the engine pivots to raise or lower the gearcase in order to maintain the most-efficient relationship between the propeller output and the surface of the water

  Note: Many modern outboard engines will not allow trim adjustments beyond 20 degrees when the boat is underway and the engine is not in neutral.
- **Trim tab**—Small fin installed under the antiventilation plate aft of the propeller and used to offset torque and other engine forces

6. Description of the effect of the trim tab on boat performance

Note: The trim tab directs the propulsive force of the lower unit at an angle in relation to the long axis of the boat. In most cases, the engine is installed at the centerline of the boat or in pairs equally spaced from the centerline of the boat. Because of the forces generated by operation of the engine, the angle of the propulsive force influences how the boat performs. Trim tabs are not normally used on boat systems with hydraulic steering.

- **A portion of the trim-tab effect is used to offset engine torque.**

  Note: In some cases, torque is overcome by offsetting the engine from the centerline so that the propulsive force is all directed opposite the direction of travel.
- **The bow moves in the direction toward which the trim tab is offset.**
- **The greater the trim-tab angle, the less force that is applied to driving the boat forward.**

  Note: Ideally, maximum propulsion is achieved by directing the water stream along the line of boat travel. However, some amount of force is required to offset the effects of torque so that force is never totally directed along the line of travel. Also, the more that the force is directed to the side, the less force that is directed to driving the boat forward.
- **The greater the trim-tab angle, the greater the turbulence that is developed in the water flow through the propeller.**

  Note: The direction of boat travel results in a flow of water relative to the engine. When the water stream is at an angle to the flow of water from the boat movement, turbulence develops as the forces work against each other. Severe turbulence can lead to cavitation. Turbulence and cavitation, in particular, reduce the amount of water that moves through the propeller and the amount of power produced by that movement of water.

Information Sheet

7. Purposes of the trim tab

Note: The trim tab is basically a small rudder set in the path of the water stream created by the propeller. The trim tab can be rotated to vary its angle in relation to the water stream. In this way, the water stream can be diverted by the trim tab so that its propulsion force is at an angle to the centerline of the boat.

- **Offsets the effects of engine torque**

  Note: The rotation of the propeller creates the twisting force known as *torque*. In effect, the entire boat is trying to rotate with the propeller shaft. However, other forces—such as the resistance of the water and the weight of the boat—overcome this tendency. Still, torque develops a momentum at the ends of the propeller blades that is of sufficient force to pull the stern of the boat in the direction of rotation, which causes the bow to move in the opposite direction. Thus, a boat with clockwise propeller rotation has a tendency to go to the left of a straight course. By diverting the water stream in the direction of propeller rotation, the stern is steered slightly in the opposite direction so that the effects of torque are offset.

- **Improves steering**

  Note: The water stream tends to spread and weaken as it flows away from the propeller. The antiventilation plate helps to stabilize the water stream vertically, while the trim tab stabilizes it horizontally. In this way, a greater amount of the force is directed to the rear of the boat. When the engine pivots to make a turn, the water stream is more effective in turning the boat.

- **May serve as a sacrificial anode**

  Note: Some boats use the trim tab as a sacrificial anode. The trim tab operates the same way as with other applications but is made of a material that allows electrical flow.

- **May serve as the exhaust port**

  Note: In some designs, the engine exhaust is vented through the trim tab. This approach increases the amount of propulsion and the trim effect proportionately to engine speed, while also allowing exhaust venting below the surface of the water.

8. Types of hydraulic circuits used in outboard-engine control systems and their purposes

Note: The purpose of a hydraulic system is to provide smooth operation with reduced effort as compared to mechanical means of transmitting power. Most outboard-engine boat systems actually use electric motors to power the hydraulic pump. Consequently, hydraulic systems are normally used on larger boats, particularly those that use engines larger than 40 horsepower. Larger boats benefit from having power-assisted systems and can generally afford the extra power output to support other systems, such as electric motors and hydraulics.

- **Tilt**—Rotates the engine vertically
- **Steering**—Pivots the engine from side to side

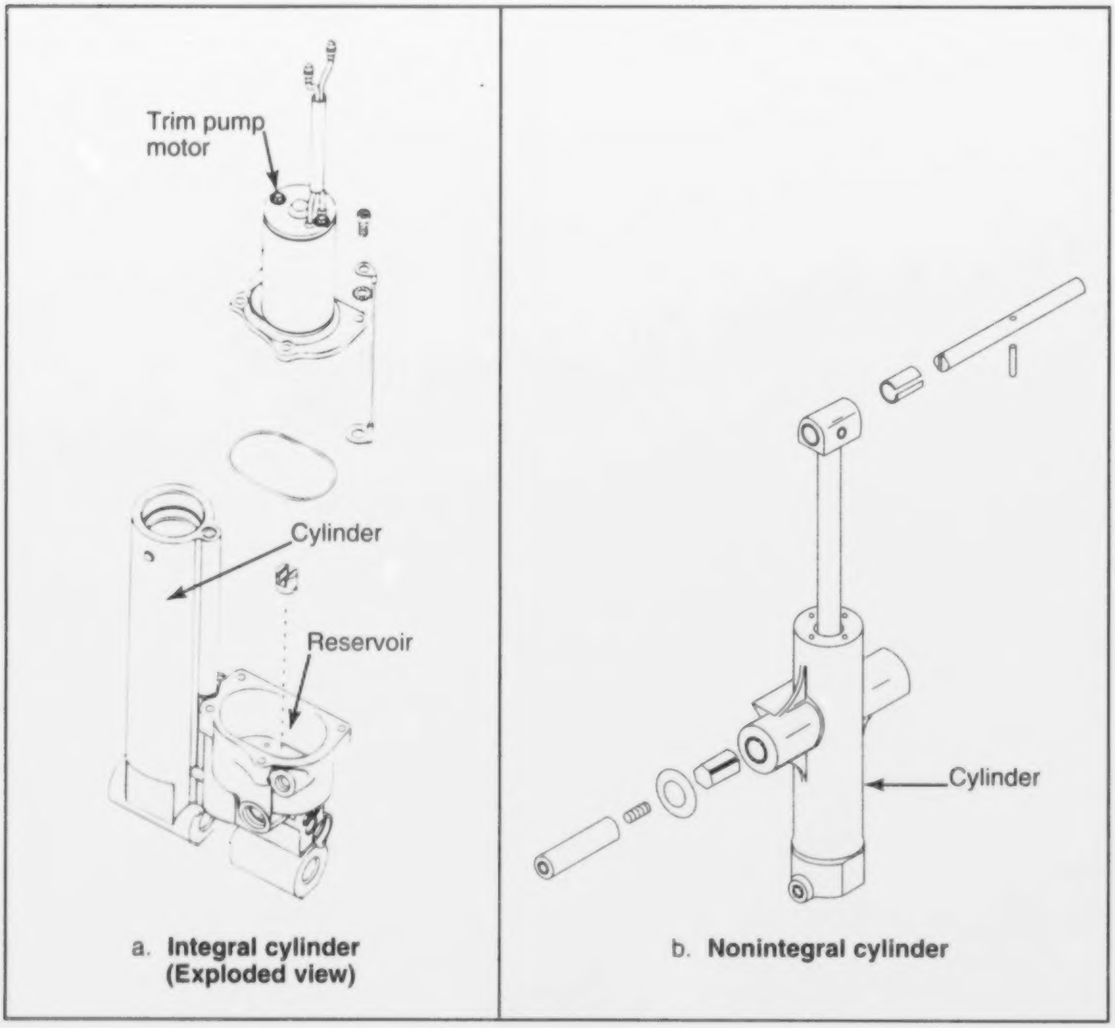
Information Sheet

9. Types of hydraulic-cylinder systems used in outboard-engine control systems

Note: Two basic designs of hydraulic cylinders are used to support the tilt, trim, and steering systems. A hydraulic cylinder may be (1) integral or (2) nonintegral. Integral cylinders are usually housed with the pump and other components, while nonintegral cylinders are separate from the pump. As a technician, you will not have to choose which type to use, but you do need to recognize the difference because of the impact each design has on service. For example, the service recommendation for a leak in a nonintegral cylinder might be to replace the cylinder, while the suggested service for an integral system might be to overhaul a cylinder.

- **Integral cylinder**
- **Nonintegral cylinder**

Figure 4: Types of hydraulic cylinders



a. **Integral cylinder (Exploded view)**

b. **Nonintegral cylinder**

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Information Sheet

10. Types of hydraulic fluids used in tilt and trim systems

Note: There are two types of hydraulic-system devices: (1) integral and (2) nonintegral. Most older systems are nonintegral systems, meaning that the system consists of several separate components. In the case of boat tilt and trim systems, nonintegral units generally have separate reservoirs and cylinders with hoses connecting these components. Integral systems usually have the reservoirs and cylinders integrated into a single unit. The type of system often determines what type of hydraulic fluid is used.

- **Engine oils**

  Note: Many nonintegral systems use automotive engine oils for hydraulic fluid. Generally, the recommended oil is SAE 10W-30 or SAW 10W-40. Manufacturers will often specify the classification of oil also, such as SF or SG.

- **Automatic-transmission fluids**

  Note: There are two major types of automatic-transmission fluid. They are generally formulated to meet requirements for either General Motors or Ford automobiles and are rated as meeting the specifications of those manufacturers. They are often marketed as Dexron® for General Motors specifications and as Mercon® or AF automatic-transmission fluid for Ford specifications. Automatic-transmission fluid is often specified for integral trim and tilt systems. Boat manufacturers frequently specify the type of automatic-transmission fluid to be used.

- **Specially formulated fluids**

  Note: Outboard-engine manufacturers often develop fluids specifically for their gear and hydraulic systems. For example, Outboard Marine Corporation (OMC)—manufacturers of Evinrude and Johnson engines—markets OMC Power Trim and Tilt Fluid.

11. Guidelines for filling hydraulic systems

- **Use the correct fluid.**

- **Do not overfill the reservoir.**

  Note: Overfilling the system is not only wasteful but it can change the pressure and temperature characteristics of the system.

- **Avoid introducing contaminants into the system.**

  Note: Dirt and particles are obvious contaminants, but oil, water, and air are also contaminants because they change the properties of the hydraulic fluid.

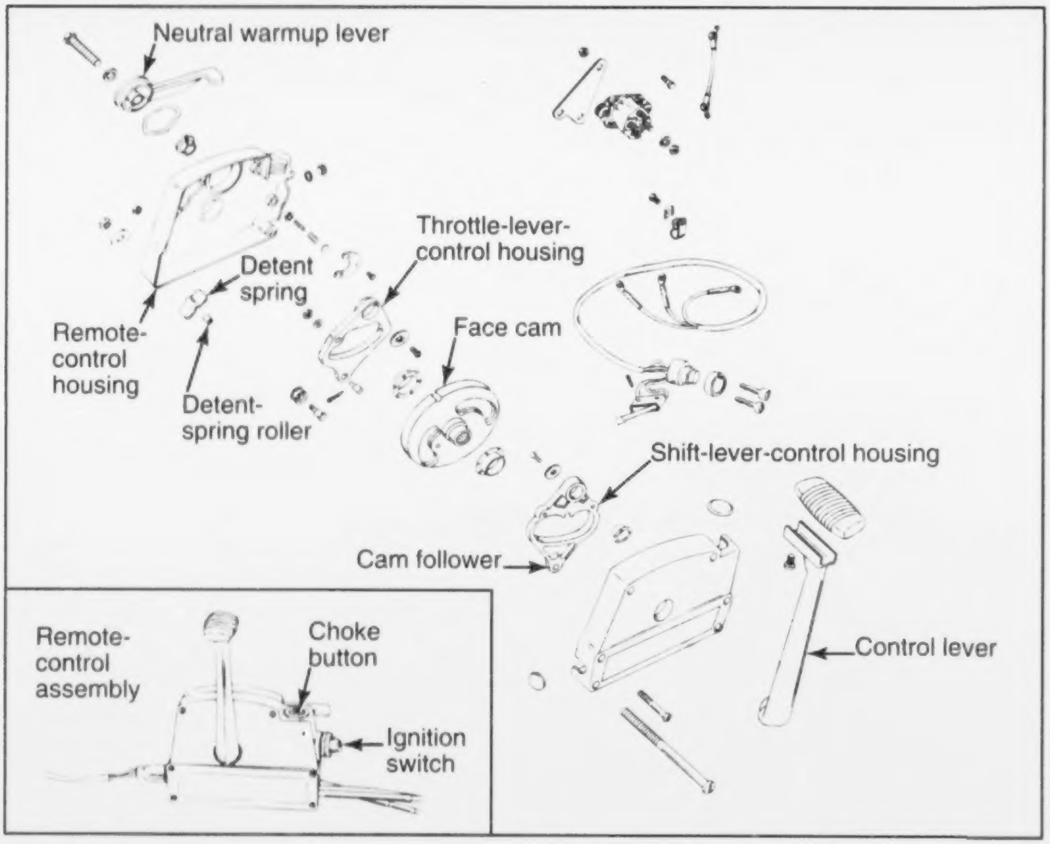
- **Bleed air from the system if required.**

- **Do not mix incompatible fluids.**

Information Sheet

12. **Major components of remote-control assemblies and their functions** (see Figure 5)

Figure 5: Major components of remote-control assemblies


Neutral warmup lever
Throttle-lever-control housing
Detent spring
Remote-control housing
Face cam
Detent-spring roller
Shift-lever-control housing
Cam follower
Control lever
Remote-control assembly
Choke button
Ignition switch

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- **Neutral warmup lever**—Limits the throttle advance during warmup with the shifter in neutral
- **Remote-control housing**—Holds the assembly components
- **Throttle lever**—Applies force to the throttle cam
- **Face cam**—Changes the orbital movement of the throttle-control lever to a vertical movement of the control cable
- **Cam follower**—Engages the face cam to transfer motion between the cam and levers
- **Shift lever**—Provides the cable connection to the shift control
- **Control lever**—Allows the operator to position the levers
- **Detent spring**—Holds the levers in a set position

Information Sheet

- **Detent-spring roller**—Promotes movement of the lever against the detent spring
- **Ignition switch**—Controls the flow of power to the starter and ignition
- **Choke button**—Enriches the fuel system for cold starting

13. **Types of safety systems used with outboard engines and their functions**

Note: Safety devices may be located on the engine or in remote-control systems. While specific outboard-engine boat systems will have various types of safety systems, those listed below are some of the more-common systems used to protect the boat operator, passengers, engine, or other equipment.

- **Emergency-stop lanyard**—Stops the flow of current to the spark plug in the event that the boat operator gets too far from the operator's seat

  Note: The emergency-stop lanyard attaches to the boat operator so that it is pulled from the circuit if the operator gets too far from the operator's seat. In this way, the boat will stop if the operator falls overboard or otherwise moves out of position to control the boat. This is equivalent to the seat switch used on many riding lawnmowers and garden tractors that shut off the engine when the operator gets off the seat.

- **Neutral-safety switch**—Prevents the engine from starting when the propeller shaft is engaged to the drive shaft

  Note: The neutral-safety switch operates in the same way as the equivalent device in other power product equipment. If the gears are engaged, the engine will not start. In this way, damage to the power-output system is prevented and the boat is not likely to lurch forward unexpectedly. Neutral-safety switches are often located in remote-control-lever housings.

- **Tilt switch**—Stops the flow of current to the spark plug if the angle of the engine is too far from vertical

  Note: Like many motorcycles, snowmobiles, and other operator-ridden equipment, modern outboard engines are often equipped with switches that cut off the ignition current if the engine is tilted too far from vertical. This prevents the engine from continuing to operate when the boat is in an unsafe position and reduces the amount of fuel that is spilled if the boat capsizes.

- **Revolution limiter**—Stops the flow of current to the spark plug in the event that the engine speed gets too high

  Note: If the load on the engine is suddenly reduced, as when the propeller breaks through the surface of the water, the revolution limiter or "rev limiter" will shut the engine down.

- **Manual-release valve**—Allows manual operation of the hydraulic tilt and trim and steering systems in the event of a failure in the hydraulic system

  Note: The manual-release valve allows pressure to be bled from the hydraulic system so that the operator can turn or tilt the engine without the resistance of the hydraulic system.

- **Sacrificial anode**—Serves as a disposable component of the engine that undergoes electrolytic deterioration so that other more-important and expensive components are less affected

  Note: When dissimilar metals are brought together in the presence of an acid, a flow of electricity develops. This is the basic principle behind a lead/acid battery, and the process also occurs with outboard-engine boat systems. The metal of the boat and metal of the engine are often different substances and many bodies of water—especially saltwater—have dissolved minerals that make them slightly or even highly acidic. This electrical flow is simply the movement of electrons from one part of the electrical circuit to another. The two poles of the circuit are referred to as the *anode* and the *cathode*, the positive and negative poles, respectively. In an electrolytic circuit, the anode gives up electrons, which eventually leads to the breakdown of the material. The use of a sacrificial anode allows this process to take place in such a way that the metal that deteriorates is inexpensive, easy to replace, and does not severely affect boat performance.

14. Principles of operation of emergency-stop lanyards

- A normally open safety switch on the engine or on the dash near the key switch keeps the ignition circuit open.

- The switch is closed by inserting one end of the lanyard into a slot on the switch, allowing the engine to start and run.

  Note: A lanyard is a short rope or cord used to fasten two objects to each other. Emergency-stop lanyards for boats are normally coiled plastic lines, similar to the cord for a telephone handset. This design allows it to stretch some so that operator has some degree of freedom in moving about. Typically, one end is attached to the operator's clothing or personal-flotation device. These are also called *tether switches*.

- The other end of the lanyard is attached to the operator.

- If the operator moves away from the safety switch farther than the reach of the lanyard, the lanyard disconnects from the switch, which is spring-loaded to open.

- When the switch opens, the ignition circuit is interrupted and the engine shuts down.

Operation and Service of Control and Safety Systems
Unit 4

Assignment Sheet 1—Determine Control-System and Safety-System Service Specifications and Parts Requirements

Name ______________________________ Date ____________________

Evaluation criteria	**Rating**
Directions have been followed.	______
Minimum of 85 percent of answers are correct.	______
Overall rating	______

Evaluator's comments ____

____

____

Introduction

Outboard-engine technicians must realize that they are normally expected to service more than just the engine. Many boats use specific systems to control tilt and trim and to assist with steering. In most cases, these systems are completely external to the engine and do not even rely directly on the engine as a power source. These systems may use hydraulic, electrical, or mechanical power sources. They may be located on the engine or remote from it. Additionally, engines and their control systems may include safety devices that affect engine operation and performance and that may vary even for the same model number of engine. This assignment sheet will help you practice your proficiency in determining specifications and parts requirements for control systems and safety systems.

Exercise

Directions

Using the resources available in your facility, determine the part numbers and specifications requested. Write your answers on the blanks provided with each question.

Assignment Sheet 1

1. What type of hydraulic fluid should be used with the following systems?

	Engine	Hydraulic system	Fluid
a.	Mariner 3 cylinder	Power tilt/trim	
b.	Mariner 85 hp	Integral-type tilt/trim	
c.	Mercury 4 cylinder	Nonintegral tilt/trim	
d.	Mercury 4 cylinder	Integral tilt/trim	
e.	Evinrude 55 hp	Tilt/trim	
f.	Johnson 4 cylinder	1988 tilt/trim	
g.	Evinrude 225 hp	Power steering	
h.	Suzuki DT200	Tilt/trim	

2. What should the pressure reading be for the pressure test in each of the following systems?

Note: If pressure readings are taken at more than one position, give the reading specified for the UP or fully loaded position.

	Engine	Hydraulic system	Pressure reading
a.	Mariner 3 cylinder	Power tilt/trim	
b.	Mariner 85 hp	Integral-type tilt/trim	
c.	Mercury 4 cylinder	Nonintegral tilt/trim	
d.	Mercury 4 cylinder	Integral tilt/trim	
e.	Evinrude 55 hp	Tilt/trim	
f.	Johnson 4 cylinder	1988 tilt/trim	
g.	Evinrude 225 hp	Power steering	
h.	Suzuki DT200	Tilt/trim	

Assignment Sheet 1

3. The following questions apply to a nonintegral power tilt/trim system as used on boats equipped with Mercury 4-cylinder engines prior to 1985.

   a. To what level should the hydraulic fluid be filled?

      Fluid level — ______________________________

   b. Do the hoses for UP motion have a larger or smaller outside diameter than those for DOWN motion? Circle the correct answer below.

      Larger Smaller

   c. How much overlap should there be between the swivel-bracket flange and clamp-bracket flange with the engine tilted fully up and stopped?

      Overlap — ______________________________

   d. During pressure testing, what is the maximum allowable pressure drop during each 15-second interval?

      Pressure drop — ______________________________

   e. What condition is indicated if, while adjusting the trim-limit switch, the cylinder rods enter the cylinders more than an additional ⅛ inch (3.2 mm) when the engine is tilted fully up?

      Condition — ______________________________

Assignment Sheet 1

4. The illustration in Figure 1 on the next page shows an exploded view of a power-trim system used with some Mariner engines, such as 40-, 50-, 55-, and 60-horsepower engines.

   a. What number in the illustration is used to label the memory piston?

      Part number — ____________________

   b. What number in the illustration is used to label the manual-release valve?

      Part number — ____________________

   c. What part number of spanner wrench is required to service this system?

      Part number — ____________________

   d. What preparation is required for the O-rings 10 and 15 prior to installation when reassembling the system?

      Preparation required — ____________________

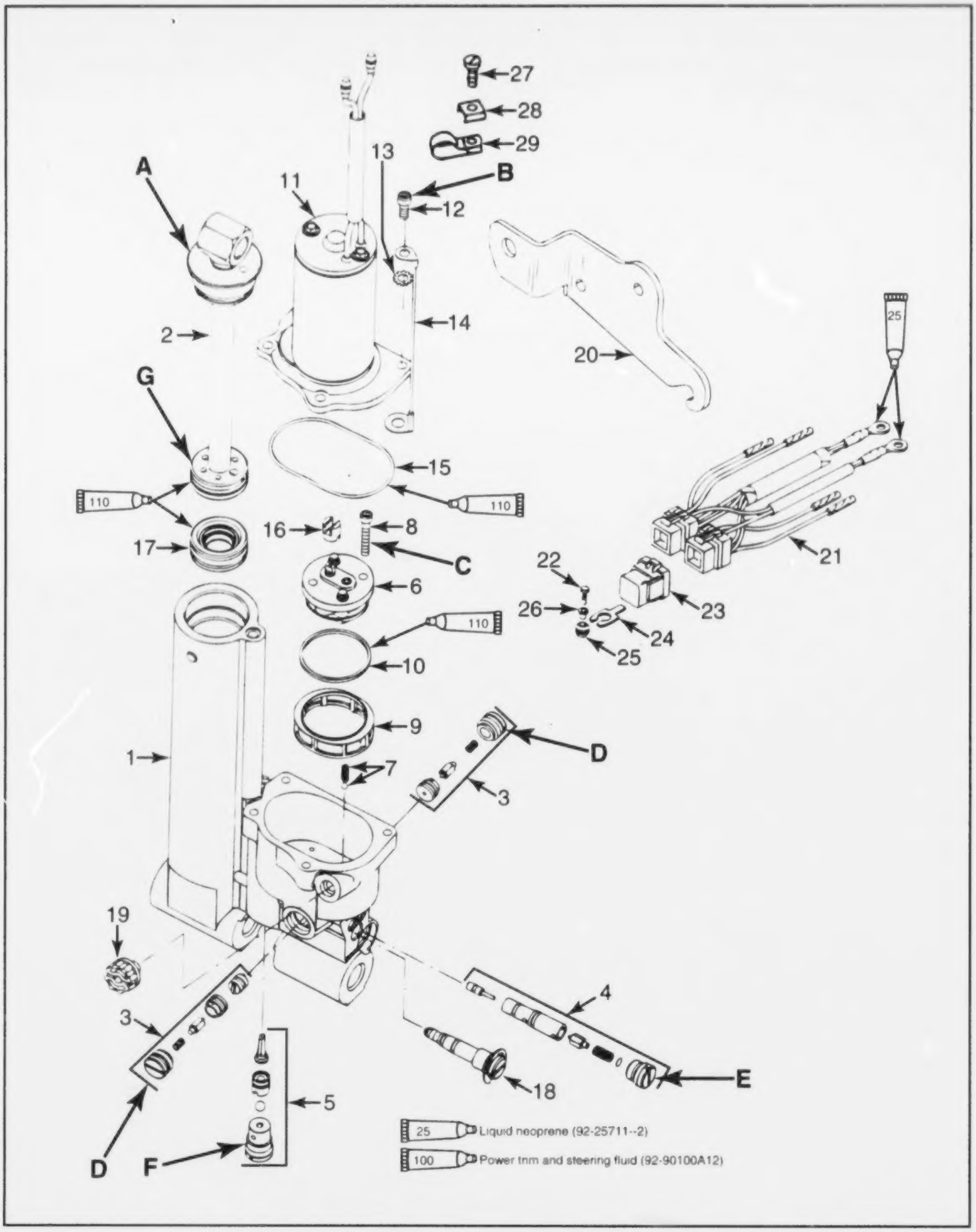
      ____

   e. What torque value should be used for each of the fasteners in the following table?

Fastener	Torque value
a. Cylinder cap (2)	
b. Pump-assembly screw (8)	
c. Pilot check assembly (3)	
d. Tilt-relief plug (4)	
e. Suction-seat plug (5)	

Assignment Sheet 1

Figure 1: Exploded view of a power-trim system used with some Mariner engines


27
28
29
13
B
A
11
12
2
14
20
25
G
15
110
110
16
8
17
C
21
6
22
26
23
110
24
25
10
9
D
1
7
3
19
4
3
E
18
5
D
F
25 Liquid neoprene (92-25711--2)
100 Power trim and steering fluid (92-90100A12)

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Assignment Sheet 1

5. Figure 2 on the next page shows the power-steering accumulator for Mercury 70- to 200-horsepower 2.5-liter and 3.0-liter engines.

   a. What number is used to indicate the hydraulic-cylinder housing in the illustration?

      Part number — ______________________________

   b. What number is used to indicate the trim check valve in the illustration?

      Part number — ______________________________

   c. When checking the power-steering-fluid level, what procedure must be performed before checking the oil level?

      Procedure — ______________________________

      ____

      ____

      ____

      ____

   d. What types of automatic-transmission fluid can be used in this system?

      Automatic-transmission fluid — ______________________

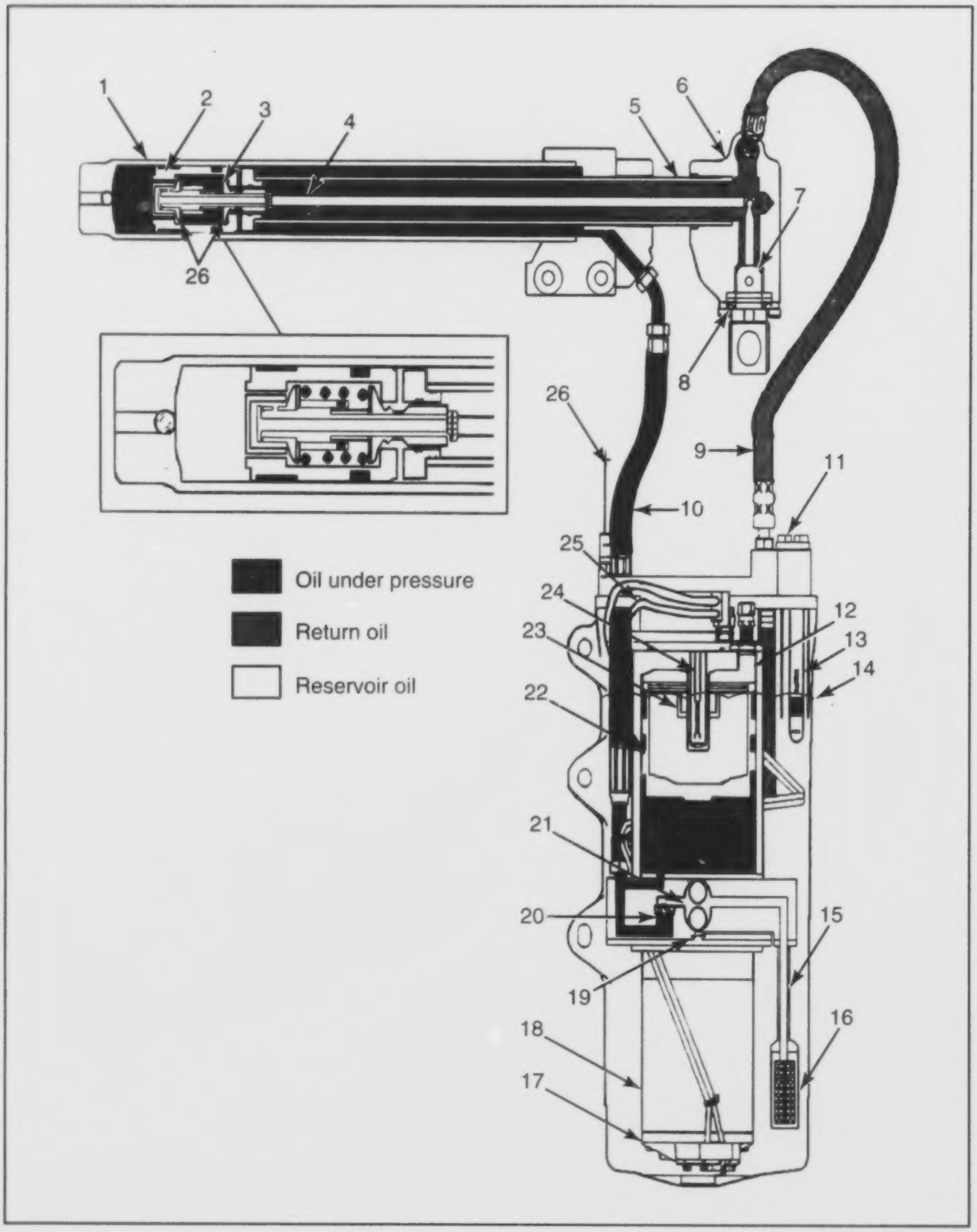
      ____

   e. What torque value is required for the link-rod bolt?

      Torque value — ______________________________

Assignment Sheet 1

Figure 2: Power-steering accumulator for Mercury 70- to 200-horsepower engines


1
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17
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19
20
21
22
23
24
25
26
26
Oil under pressure
Return oil
Reservoir oil

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Assignment Sheet 1

6. The illustration in Figure 3 on the next page shows the wiring diagram of the speed-control adjustment for a Mercury 4 or 40 engine.

   a. What color of wire is used to join the trigger coil to the stator?

   Wire color — ______________________________

   b. Which of the following is **not** a correct specification for setting the ignition timing? Circle the correct answer.

   - Gap between throttle cam and cam follower at 0.005-0.015 inch
   - Timing light on Number 2 spark plug
   - Engine running at 1000-1500 rpm

   c. What is the maximum ignition-timing setting?

   Maximum setting — ______________________________

   d. What is the desired resistance for the wire between the stator and the switch box?

   Wire resistance — ______________________________

   e. What is the recommended difference between the ignition timing and advance reading, and what is the relationship between the two readings—is the ignition or advance reading higher?

   ____

   ____

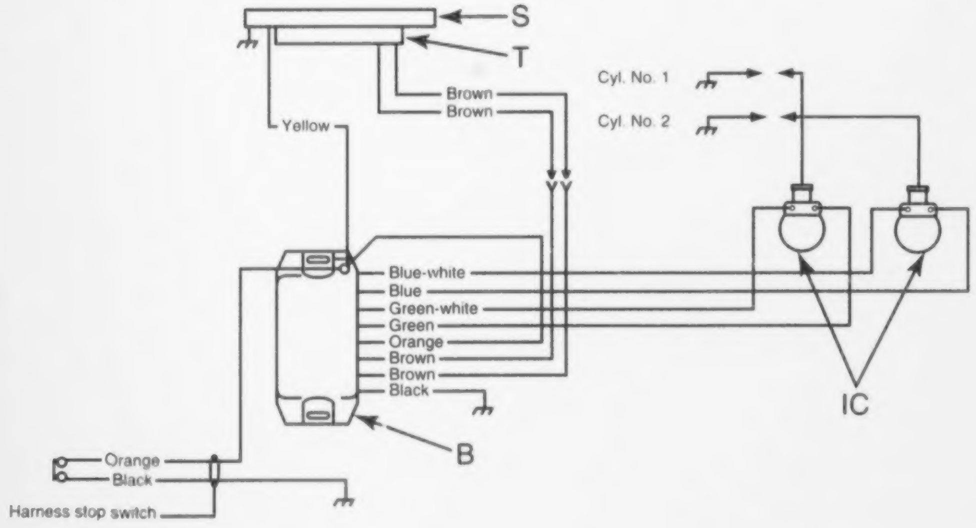
   ____

   ____

   ____

Assignment Sheet 1

Figure 3: Wiring schematic for Merc 4 and 40


S
T
Brown
Brown
Yellow
Cyl. No. 1
Cyl. No. 2
Blue-white
Blue
Green-white
Green
Orange
Brown
Brown
Black
IC
B
Orange
Black
Harness stop switch

Trigger module has two brown leads on models prior to 1978 and a brown lead and a white lead on models after 1977.

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Assignment Sheet 1

7. The following questions apply to a Mercury Commander two-lever-console remote control.

   a. What type of lubricant is recommended for the cable-pulley mounting shafts and cable grooves?

      Lubricant — ______________________________

   b. What is the recommended cable deflection when pulled out with a 5-pound force?

      Deflection — ______________________________

   c. What is the recommended torque for the handle set screws?

      Torque — ______________________________

   d. When adjusting the neutral safety switch, what gear position and throttle setting should be used?

      Gear position — ______________________________

      Throttle setting — ______________________________

   e. Is the shift handle black or red?

      Color — ______________________________

Operation and Service of Control and Safety Systems
Unit 4

Job Sheet 1—Perform Routine Maintenance on Steering Systems

Introduction This job sheet covers the routine maintenance associated with steering systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Adjust steering linkages
- Lubricate gears, linkages, and other moving parts
- Adjust fluid levels for hydraulic systems

Procedure

1. Study the objectives in the information sheet and complete the assignment sheet.

2. Watch your instructor's demonstration of performing routine maintenance on steering systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one steering system. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with a steering system.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 1

Worksheet—Perform Routine Maintenance on Steering Systems

Name ______________________ Attempt number ________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 1

Worksheet—Perform Routine Maintenance on Steering Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Control and Safety Systems
Unit 4

Job Sheet 2—Repair Steering Systems

Introduction

This job sheet covers the repair procedures associated with steering systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace hydraulic components and other components, including columns, cables, etc.
- Overhaul subsystems, including hydraulic cylinders, pumps, etc.
- Perform adjustments to return system to original specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheet.

2. Watch your instructor's demonstration of repairing steering systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one steering system. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with a steering system that requires repair.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 2

Worksheet—Repair Steering Systems

Name ______________________ Attempt number ________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 2

Worksheet—Repair Steering Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	________
Procedures completed correctly.	________
Proper tools used correctly.	________
Safety precautions observed.	________
Service meets specifications.	________
Clean-up and follow-up actions adequate.	________
Overall rating	________

Evaluator's comments ____

____

____

Operation and Service of Control and Safety Systems
Unit 4

Job Sheet 3—Perform Routine Maintenance on Tilt and Trim Systems

Introduction

This job sheet covers the routine maintenance associated with trim and tilt systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Inspect components
- Adjust hydraulic-fluid levels
- Adjust trim-position sensor and trim-limit switch
- Test electrical components

Procedure

1. Study the objectives in the information sheet and complete the assignment sheet.

2. Watch your instructor's demonstration of performing routine maintenance on tilt and trim systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one tilt and trim system. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with a tilt and trim system.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/ materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 3

Worksheet—Perform Routine Maintenance on Tilt and Trim Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ____

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________________

Job Sheet 3

Worksheet—Perform Routine Maintenance on Tilt and Trim Systems

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Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

____

____

Operation and Service of Control and Safety Systems
Unit 4

Job Sheet 4—Repair Tilt and Trim Systems

Introduction

This job sheet covers the repair procedures associated with tilt and trim systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace components, including sensors, limiting switches, wiring, hydraulic lines, pumps, cylinders, etc.
- Overhaul subsystems, including hydraulic pumps and cylinders
- Perform adjustments to return system to original specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheet.

2. Watch your instructor's demonstration of repairing tilt and trim systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one tilt and trim system. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with a tilt and trim system.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 4

Worksheet—Repair Tilt and Trim Systems

Name   Attempt number

Date

Part A: **Pre-performance check**

Job

- Complete the following information concerning the assigned equipment.

  Equipment brand

  Equipment model/type and code

- Complete the following service-manual information.

  Service-manual title

  Section/page number of procedure

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature

Job Sheet 4

Worksheet—Repair Tilt and Trim Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

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____

Operation and Service of Control and Safety Systems
Unit 4

Job Sheet 5—Perform Routine Maintenance on Remote-Control Systems

Introduction

This job sheet covers the routine maintenance associated with remote-control systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Inspect components, including control box, cables, wiring, etc.
- Lubricate cables, levers, etc.
- Adjust alignments and clearances

Procedure

1. Study the objectives in the information sheet and complete the assignment sheet.

2. Watch your instructor's demonstration of performing routine maintenance on remote-control systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one remote-control system. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine that uses a remote-control system.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 5

Worksheet—Perform Routine Maintenance on Remote-Control Systems

Name ______________________________ Attempt number __________

Date ______________________________

Part A: Pre-performance check

Job ______________________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________________

  Equipment model/type and code ______________________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________________

  Section/page number of procedure ______________________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________________

Job Sheet 5

Worksheet—Perform Routine Maintenance on Remote-Control Systems

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Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

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____

Operation and Service of Control and Safety Systems
Unit 4

Job Sheet 6—Repair Remote-Control Systems

Introduction

This job sheet covers the repair procedures associated with remote-control systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Replace components, including cables, control boxes, linkages, etc.
- Overhaul subsystems, including control boxes and shift linkages
- Perform adjustments to return system to original specifications

Procedure

1. Study the objectives in the information sheet and complete the assignment sheet.
2. Watch your instructor's demonstration of repairing remote-control systems and any supporting media provided by your instructor.
3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one remote-control system. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.
4. Ask your instructor to provide you with an outboard engine that uses a remote-control system.
5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.
6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.
7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 6

Worksheet—Repair Remote-Control Systems

Name ______________________ Attempt number __________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 6

Worksheet—Repair Remote-Control Systems

Part B: **Performance evaluation**

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

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Operation and Service of Control and Safety Systems
Unit 4

Job Sheet 7—Service Safety Systems

Introduction

This job sheet covers the service procedures associated with safety systems. You will accomplish these tasks by following the appropriate procedures in the manufacturer's service manual. While the specific procedures will depend on the equipment design and manufacturer's processes, the general tasks that may be performed under this procedure include

- Inspect components, including lanyards, switches, valves, etc.
- Adjust switches
- Ensure proper connection and positioning of safety devices
- Replace components, including lanyards, switches, valves, etc.

Procedure

1. Study the objectives in the information sheet and complete the assignment sheet.

2. Watch your instructor's demonstration of servicing safety systems and any supporting media provided by your instructor.

3. Review the following worksheet associated with this job sheet. You may be required to accomplish this job sheet for more than one safety system. Check with your instructor, and obtain a copy of the worksheet for each attempt that will be required.

4. Ask your instructor to provide you with an outboard engine that uses one or more safety systems.

5. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the service information you have located and the equipment/materials you have listed for performing the procedure on the equipment assigned.

6. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

7. Using the instructor-approved service information and equipment/materials list, perform the appropriate procedure. Your instructor will rate your performance using the evaluation criteria listed in the performance evaluation on the worksheet.

Job Sheet 7

Worksheet—Service Safety Systems

Name ______________________ Attempt number ________

Date ______________________

Part A: Pre-performance check

Job ______________________

- Complete the following information concerning the assigned equipment.

  Equipment brand ______________________

  Equipment model/type and code ______________________

  ____

- Complete the following service-manual information.

  Service-manual title ______________________

  Section/page number of procedure ______________________

- List type and number of replacement parts.

- List special equipment/materials required for procedure.

Instructor's signature ______________________

Job Sheet 7

Worksheet—Service Safety Systems

Part B: Performance evaluation

Evaluation criteria	**Rating**
Correct procedures identified for assigned equipment.	______
Procedures completed correctly.	______
Proper tools used correctly.	______
Safety precautions observed.	______
Service meets specifications.	______
Clean-up and follow-up actions adequate.	______
Overall rating	______

Evaluator's comments ____

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